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Date: March 14, 2008

RECIPIENT	COMPANY	PHONE NO.	FAX NO.
Ms. Paula Kidwell	USPTO	703-308-9140 Ext. 216	571-270-9881

FROM: Robert W. Diehl
PHONE: (312) 460-5557
RE: Masumi OKUO et al
U.S. Serial No. 10/517,357
Based on PCT/JP03/06339
Attorney Docket: 37569-407800

REPLY FAX NO.: (312) 460-7557

File No:	37569-407800	Number of Pages, Including Cover: 108
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| <input type="checkbox"/> Hard copy to follow | <input checked="" type="checkbox"/> Hard copy will not follow |
| <input checked="" type="checkbox"/> Per your request | <input type="checkbox"/> Please review and revise if necessary |
| <input type="checkbox"/> Please telephone me | |

MESSAGE:

Attached is a copy of correspondence sent to the USPTO prior to November 2005. Should you need anything further please do not hesitate to contact Connie Henry @ 312-460-5745. Thank you.

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CHI 11435747.1 / 37569-407800

Stamp of the United States Patent and Trademark Office Box Patent Application
acknowledging receipt of the following items is requested:

Docket No. 37569-407800

Inventor: OKUO et al

Title: PHOTOCURABLE RESIN COMPOSITION FOR FORMING OVERCOATS
RGB PIXELS, BLACK MATRIXES...

Serial No. 10/517,357

- * Transmittal Letter Concerning 371 Filing (in duplicate)
- * Copy of PCT Notification of Transmittal of Copies of Translation of the International Preliminary Examination Report
- * Certificate of First Class Mailing and Postcard

Stamp of the United States Patent and Trademark Office Box Patent Application
acknowledging receipt of the following items is requested:

Docket No. 37569-407800 ✓

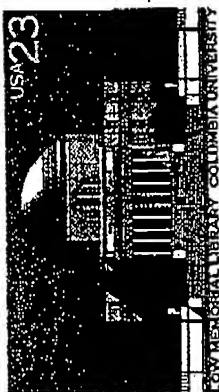
Inventor: OKUO et al

Title: PHOTOCURABLE RESIN COMPOSITION FOR FORMING OVERCOATS
RGB PIXELS, BLACK MATRIXES...

Serial No. 10/517,357

JC04 Rec'd PCT/PTO 23 JUN 2005

- * Transmittal Letter Concerning 371 Filing (in duplicate)
- * Copy of PCT Notification of Transmittal of Copies of Translation of the International Preliminary Examination Report
- * Certificate of First Class Mailing and Postcard



Timothy J. Keefe
Seyfarth Shaw
55 East Monroe
Chicago, Illinois 60603
Suite 4200

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PTO-1390 (Rev. 02-2005)

Approved for use through 3/31/2007. OMB 0651-0021
U.S. Patent and Trademark Office, U.S. DEPARTMENT OF COMMERCE

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A SUBMISSION UNDER 35 U.S.C. 371		ATTORNEY'S DOCKET NUMBER 37569-407800
INTERNATIONAL APPLICATION NO. PCT/JP03/06339	INTERNATIONAL FILING DATE 21 May 2003	U.S. APPLICATION NO. (If known, see 37 CFR 1.5) 10/517,357
TITLE OF INVENTION PHOTOCURABLE RESIN COMPOSITION FOR FORMING OVERCOATS, RGB PIXELS, BLACK MATRIXES.		PRIORITY DATE CLAIMED 24 May 2002
APPLICANT(S) FOR DO/EO/US Masami OKUO, Kensaku SONODA, Chihiro IMASE, Yoshikazu NAKASHIMA, Shinji HAYASHI, Akitaka NISHIO		
Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:		
1. <input type="checkbox"/> This is a FIRST submission of items concerning a submission under 35 U.S.C. 371. 2. <input checked="" type="checkbox"/> This is a SECOND or SUBSEQUENT submission of items concerning a submission under 35 U.S.C. 371. 3. <input type="checkbox"/> This is an express request to begin national examination procedures (35 U.S.C. 371(f)). The submission must include items (5), (6), (9) and (21) indicated below. 4. <input type="checkbox"/> The US has been elected (Article 31). 5. <input type="checkbox"/> A copy of the International Application as filed (35 U.S.C. 371(c)(2)) a. <input type="checkbox"/> is attached hereto (required only if not communicated by the International Bureau). b. <input type="checkbox"/> has been communicated by the International Bureau. c. <input type="checkbox"/> is not required, as the application was filed in the United States Receiving Office (RO/US). 6. <input type="checkbox"/> An English language translation of the International Application as filed (35 U.S.C. 371(c)(2)). a. <input type="checkbox"/> is attached hereto. b. <input type="checkbox"/> has been previously submitted under 35 U.S.C. 154(d)(4). 7. <input type="checkbox"/> Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371(c)(3)) a. <input type="checkbox"/> are attached hereto (required only if not communicated by the International Bureau). b. <input type="checkbox"/> have been communicated by the International Bureau. c. <input type="checkbox"/> have not been made; however, the time limit for making such amendments has NOT expired. d. <input type="checkbox"/> have not been made and will not be made. 8. <input type="checkbox"/> An English language translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)). 9. <input type="checkbox"/> An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4)). 10. <input checked="" type="checkbox"/> An English language translation of the annexes of the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371(c)(5)). 		
Items 11 to 20 below concern document(s) or information included:		
11. <input type="checkbox"/> An Information Disclosure Statement under 37 CFR 1.97 and 1.98. 12. <input type="checkbox"/> An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included. 13. <input type="checkbox"/> A preliminary amendment. 14. <input type="checkbox"/> An Application Data Sheet under 37 CFR 1.76. 15. <input type="checkbox"/> A substitute specification. 16. <input type="checkbox"/> A power of attorney and/or change of address letter. 17. <input type="checkbox"/> A computer-readable form of the sequence listing in accordance with PCT Rule 13ter.2 and 37 CFR 1.821- 1.825. 18. <input type="checkbox"/> A second copy of the published International Application under 35 U.S.C. 154(d)(4). 19. <input type="checkbox"/> A second copy of the English language translation of the International Application under 35 U.S.C. 154(d)(4). 20. <input type="checkbox"/> Other items or information:		

This collection of information is required by 37 CFR 1.414 and 1.491-1.492. The information is required to obtain or retain a benefit by the public, which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and 1.14. This collection is estimated to take 15 minutes to complete, including gathering information, preparing, and submitting the completed form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Mail Stop PCT, Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.

PTO-1390 (Rev. 02-2005)

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U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE

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U.S. APPLICATION NO. (if known, see 37 CFR 1.5)		INTERNATIONAL APPLICATION NO.		ATTORNEY'S DOCKET NUMBER	
10/517,357		PCT/JP03/06339		37569-407800	
The following fees are submitted:				CALCULATIONS	PTO USE ONLY
21. <input type="checkbox"/> Basic national fee..... \$300				\$	
22. <input type="checkbox"/> Examination fee					
If International preliminary examination report prepared by USPTO and all claims satisfy provisions of PCT Article 33(1)-(4)..... \$100				\$	
All other situations..... \$200					
23. <input type="checkbox"/> Search fee					
Search fee (37 CFR 1.445(a)(2)) has been paid on the international application to the USPTO as an International Searching Authority..... \$100					
International Search Report prepared and provided to the Office..... \$400					
All other situations..... \$500				\$	
TOTAL OF 21, 22 and 23 =				\$	
<input type="checkbox"/> Additional fee for specification and drawings filed in paper over 100 sheets (excluding sequence listing or computer program listing filed in an electronic medium). The fee is \$250 for each additional 50 sheets of paper or fraction thereof.					
Total Sheets	Extra sheets	Number of each additional 50 or fraction thereof (round up to a whole number)	RATE		
- 100 =	/50 =		x \$250	\$	
Surcharge of \$130.00 for furnishing the oath or declaration later than 30 months from the earliest claimed priority date (37 CFR 1.492(h)).				\$	
CLAIMS	NUMBER FILED	NUMBER EXTRA	RATE	\$	
Total claims	-20 =		x \$50	\$	
Independent claims	-3 =		x \$200	\$	
MULTIPLE DEPENDENT CLAIM(S) (if applicable)			+ \$360	\$	
TOTAL OF ABOVE CALCULATIONS =				\$	
<input type="checkbox"/> Applicant claims small entity status. See 37 CFR 1.27. Fees above are reduced by 1/2.				\$	
SUBTOTAL =				\$	
Processing fee of \$130.00 for furnishing the English translation later than 30 months from the earliest claimed priority date (37 CFR 1.492(i)).				+	\$
TOTAL NATIONAL FEE =				\$	
Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31). \$40.00 per property				+	\$
TOTAL FEES ENCLOSED =				\$	
				Amount to be refunded:	\$
				Amount to be charged:	\$
a. <input type="checkbox"/> A check in the amount of \$ _____ to cover the above fees is enclosed.					
b. <input type="checkbox"/> Please charge my Deposit Account No. _____ in the amount of \$ _____ to cover the above fees. A duplicate copy of this sheet is enclosed.					
c. <input checked="" type="checkbox"/> The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. <u>191351</u> . A duplicate copy of this sheet is enclosed.					
d. <input type="checkbox"/> Fees are to be charged to a credit card. WARNING: Information on this form may become public. Credit card information should not be included on this form. Provide credit card information and authorization on PTO-2038.					
NOTE: Where an appropriate time limit under 37 CFR 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the International Application to pending status.					
SEND ALL CORRESPONDENCE TO:					
Timothy J. Keefer SEYFARTH SHAW LLP 55 W. Monroe Street Chicago, IL 60603					
SIGNATURE Timothy J. Keefer NAME 35,567 REGISTRATION NUMBER					

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U.S. Patent and Trademark Office: U.S. DEPARTMENT OF COMMERCE

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**TRANSMITTAL LETTER TO THE UNITED STATES
DESIGNATED/ELECTED OFFICE (DO/EO/US)
CONCERNING A SUBMISSION UNDER 35 U.S.C. 371**

ATTORNEY'S DOCKET NUMBER

37569-407800

U.S. APPLICATION NO. (If known, see 37 CFR 1.5)

10/517,357

INTERNATIONAL APPLICATION NO.

PCT/JP03/06339

INTERNATIONAL FILING DATE

21 May 2003

PRIORITY DATE CLAIMED

24 May 2002

TITLE OF INVENTION

PHOTOCURABLE RESIN COMPOSITION FOR FORMING OVERCOATS, RGB PIXELS, BLACK MATRIXES...

APPLICANT(S) FOR DO/EO/US

Masami OKUO, Kensaku SONODA, Chihiro IMASE, Yoshikazu NAKASHIMA, Shinji HAYASHI, Akitaka NISHIO

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. ☐ This is a FIRST submission of items concerning a submission under 35 U.S.C. 371.
2. ☒ This is a SECOND or SUBSEQUENT submission of items concerning a submission under 35 U.S.C. 371.
3. ☐ This is an express request to begin national examination procedures (35 U.S.C. 371(f)). The submission must include items (5), (6), (9) and (21) indicated below.
4. ☐ The US has been elected (Article 31).
5. ☐ A copy of the International Application as filed (35 U.S.C. 371(c)(2))
 - a. ☐ is attached hereto (required only if not communicated by the International Bureau).
 - b. ☐ has been communicated by the International Bureau.
 - c. ☐ is not required, as the application was filed in the United States Receiving Office (RO/US).
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 - a. ☐ are attached hereto (required only if not communicated by the International Bureau).
 - b. ☐ have been communicated by the International Bureau.
 - c. ☐ have not been made; however, the time limit for making such amendments has NOT expired.
 - d. ☐ have not been made and will not be made.
8. ☐ An English language translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).
9. ☐ An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4)).
10. ☒ An English language translation of the annexes of the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371(c)(5)).

Items 11 to 20 below concern document(s) or information included:

11. ☐ An Information Disclosure Statement under 37 CFR 1.97 and 1.98.
12. ☐ An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
13. ☐ A preliminary amendment.
14. ☐ An Application Data Sheet under 37 CFR 1.76.
15. ☐ A substitute specification.
16. ☐ A power of attorney and/or change of address letter.
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19. ☐ A second copy of the English language translation of the International Application under 35 U.S.C. 154(d)(4).
20. ☐ Other items or information:

is collection of information is required by 37 CFR 1.414 and 1.491-1.492. The information is required to obtain or retain a benefit by the public, which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and 1.14. This collection is estimated to take 15 minutes to complete, including gathering information, preparing, and submitting the completed form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Mail Stop PCT, Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.

PTO-1390 (Rev. 02-2005)

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U.S. APPLICATION NO. (if known, see 37 CFR 1.5) 10/517,357		INTERNATIONAL APPLICATION NO. PCT/JP03/06339		ATTORNEY'S DOCKET NUMBER 37569-407800	
The following fees are submitted:				CALCULATIONS	PTO USE ONLY
21. <input type="checkbox"/> Basic national fee..... \$300				\$	
22. <input type="checkbox"/> Examination fee					
If International preliminary examination report prepared by USPTO and it aims satisfy provisions of PCT Article 33(1)-(4)..... \$100				\$	
All other situations..... \$200					
23. <input type="checkbox"/> Search fee					
Search fee (37 CFR 1.445(a)(2)) has been paid on the international application to the USPTO as an International Searching Authority..... \$100					
International Search Report prepared and provided to the Office..... \$400					
All other situations..... \$500				\$	
TOTAL OF 21, 22 and 23 =				\$	
<input type="checkbox"/> Additional fee for specification and drawings filed in paper over 100 sheets (excluding sequence listing or computer program listing filed in an electronic medium). The fee is \$250 for each additional 50 sheets of paper or fraction thereof.					
Total Sheets	Extra sheets	Number of each additional 50 or fraction thereof (round up to a whole number)	RATE		
- 100 =	/50 =		x \$250	\$	
Surcharge of \$130.00 for furnishing the oath or declaration later than 30 months from the earliest claimed priority date (37 CFR 1.492(h)).				\$	
CLAIMS	NUMBER FILED	NUMBER EXTRA	RATE	\$	
Total claims	-20 =		x \$50	\$	
Independent claims	-3 =		x \$200	\$	
MULTIPLE DEPENDENT CLAIM(S) (if applicable)			+ \$360	\$	
TOTAL OF ABOVE CALCULATIONS =				\$	
<input type="checkbox"/> Applicant claims small entity status. See 37 CFR 1.27. Fees above are reduced by 1/2.				\$	
SUBTOTAL =				\$	
Processing fee of \$130.00 for furnishing the English translation later than 30 months from the earliest claimed priority date (37 CFR 1.492(i)).				+	\$
TOTAL NATIONAL FEE =				\$	
Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31). \$40.00 per property				+	\$
TOTAL FEES ENCLOSED =				\$	
				Amount to be refunded:	\$
				Amount to be charged:	\$

a. ☐ A check in the amount of \$ _____ to cover the above fees is enclosed.

b. ☐ Please charge my Deposit Account No. _____ in the amount of \$ _____ to cover the above fees. A duplicate copy of this sheet is enclosed.

c. ☒ The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. 191351. A duplicate copy of this sheet is enclosed.

1. ☐ Fees are to be charged to a credit card. **WARNING:** Information on this form may become public. Credit card information should not be included on this form. Provide credit card information and authorization on PTO-2038.

NOTE: Where an appropriate time limit under 37 CFR 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the International Application to pending status.

SEND ALL CORRESPONDENCE TO:

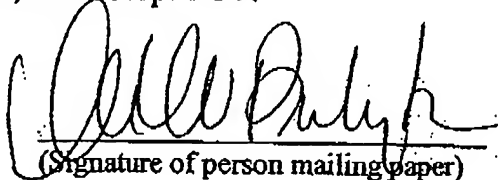
Timothy J. Keefer
SEYFARTH SHAW LLP
35 W. Monroe Street
Chicago, IL 60603

SIGNATURE
Timothy J. Keefer
NAME
35,567
REGISTRATION NUMBER

CERTIFICATE OF MAILINGDATE OF DEPOSIT: June 17, 2005

I hereby certify that the attached paper (along with any paper referred to as being attached or enclosed) is being deposited with the United States Postal Service First Class Mail on the date indicated above and is addressed to Commissioner for Patents, Box 1450, Alexandria, VA. 22313-1450, Mail Stop: PCT.

Christine Pavlyk
(Name of person mailing paper)


(Signature of person mailing paper)

PCT

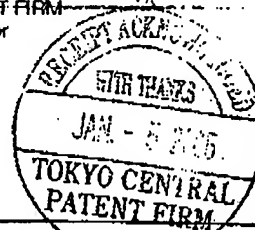
**NOTIFICATION OF TRANSMITTAL
OF COPIES OF TRANSLATION
OF THE INTERNATIONAL PRELIMINARY
EXAMINATION REPORT**

(PCT Rule 72.2)

From the INTERNATIONAL BUREAU

To:

KISHIMOTO, Tatsuhito
c/o TOKYO CENTRAL PATENT FIRM
Oak Building Kyobashi 4th Floor
16-10, Kyobashi 1-chome
Chuo-ku, Tokyo 104-0031
JAPON



Date of mailing (day/month/year) 23 December 2004 (23.12.2004)	IMPORTANT NOTIFICATION
Applicant's or agent's file reference 010218PCT	
International application No. PCT/JP2003/006339	International filing date (day/month/year) 21 May 2003 (21.05.2003)
Applicant DAI NIPPON PRINTING CO., LTD. et al	

1. Transmittal of the translation to the applicant.

The International Bureau transmits herewith a copy of the English translation made by the International Bureau of the international preliminary examination report established by the International Preliminary Examining Authority.

2. Transmittal of the copy of the translation to the elected Offices.

The International Bureau notifies the applicant that copies of that translation have been transmitted to the following elected Offices requiring such translation:

CN, KR

The following elected Offices, having waived the requirement for such a transmittal at this time, will receive copies of that translation from the International Bureau only upon their request:

US

3. Reminder regarding translation into (one of) the official language(s) of the elected Office(s).

The applicant is reminded that, where a translation of the international application must be furnished to an elected Office, that translation must contain a translation of any annexes to the international preliminary examination report.

It is the applicant's responsibility to prepare and furnish such translation directly to each elected Office concerned (Rule 74.1). See Volume II of the PCT Applicant's Guide for further details.

The International Bureau of WIPO
34, chemin des Colombettes
1211 Geneva 20, Switzerland

Authorized officer

Yoshiko Kuwahara

Translation

PATENT COOPERATION TREATY

PCT/JP2003/006339



PCT

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

Applicant's or agent's file reference 010218PCT	FOR FURTHER ACTION See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416)	
International application No. PCT/JP2003/006339	International filing date (day/month/year) 21 May 2003 (21.05.2003)	Priority date (day/month/year) 24 May 2002 (24.05.2002)
International Patent Classification (IPC) or national classification and IPC G02B 5/20, G03F 7/027, G02F 1/1335, 1/1339		
Applicant DAI NIPPON PRINTING CO., LTD.		

1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.

2. This REPORT consists of a total of 3 sheets, including this cover sheet.

☐ This report is also accompanied by ANNEXES, i.e., sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).

These annexes consist of a total of sheets.

3. This report contains indications relating to the following items:

- I ☒ Basis of the report
- II ☐ Priority
- III ☐ Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
- IV ☐ Lack of unity of invention
- V ☒ Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
- VI ☐ Certain documents cited
- VII ☐ Certain defects in the international application
- VIII ☐ Certain observations on the international application

Date of submission of the demand 18 November 2003 (18.11.2003)	Date of completion of this report 08 March 2004 (08.03.2004)
Name and mailing address of the IPEA/IP	Authorized officer
Facsimile No.	Telephone No.

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No.

PCT/JP2003/006339

I. Basis of the report

1. With regard to the elements of the international application:*

- ☒ the international application as originally filed
- ☐ the description:
 pages _____, as originally filed
 pages _____, filed with the demand
 pages _____, filed with the letter of _____
- ☐ the claims:
 pages _____, as originally filed
 pages _____, as amended (together with any statement under Article 19
 pages _____, filed with the demand
 pages _____, filed with the letter of _____
- ☐ the drawings:
 pages _____, as originally filed
 pages _____, filed with the demand
 pages _____, filed with the letter of _____
- ☐ the sequence listing part of the description:
 pages _____, as originally filed
 pages _____, filed with the demand
 pages _____, filed with the letter of _____

2. With regard to the language, all the elements marked above were available or furnished to this Authority in the language in which the international application was filed, unless otherwise indicated under this item.

- These elements were available or furnished to this Authority in the following language _____ which is:
- ☐ the language of a translation furnished for the purposes of international search (under Rule 23.1(b)).
- ☐ the language of publication of the international application (under Rule 48.3(b)).
- ☐ the language of the translation furnished for the purposes of international preliminary examination (under Rule 55.2 and/or 55.3).

3. With regard to any nucleotide and/or amino acid sequence disclosed in the international application, the international preliminary examination was carried out on the basis of the sequence listing:

- ☐ contained in the international application in written form.
- ☐ filed together with the international application in computer readable form.
- ☐ furnished subsequently to this Authority in written form.
- ☐ furnished subsequently to this Authority in computer readable form.
- ☐ The statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.
- ☐ The statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished.

4. ☐ The amendments have resulted in the cancellation of:

- ☐ the description, pages _____
- ☐ the claims, Nos. _____
- ☐ the drawings, sheets/fig. _____

5. ☐ This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed, as indicated in the Supplemental Box (Rule 70.2(c)).**

* Replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to this report since they do not contain amendments (Rule 70.16 and 70.17).

** Any replacement sheet containing such amendments must be referred to under item 1 and annexed to this report.

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No.

PCT/JP03/06339

V. Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Claims	1-17	YES
	Claims		NO
Inventive step (IS)	Claims	1-17	YES
	Claims		NO
Industrial applicability (IA)	Claims	1-17	YES
	Claims		NO

2. Citations and explanations

Document 1: JP, 2002-14468, A (Mitsubishi Chemical Corp.), 18 January, 2002 (18.01.02)
Document 2: JP, 2001-337450, A (Mitsubishi Chemical Corp.), 7 December, 2001 (07.12.01)
Document 3: JP, 2002-12607, A (Mitsubishi Chemical Corp.), 15 January, 2002 (15.01.02)

The subject matters of claims 1-17 appear to involve an inventive step in view of documents 1-3 cited in the ISR. Those documents do not describe that, in a color filter, a light-hardening resin composition that contains a copolymer having a molecular structure of unit components represented by the formula (1) linked is used.

Stamp of the United States Patent and Trademark Office Box Patent Application
acknowledging receipt of the following items is requested:

Docket No. 37569-407800

Inventor: OKUO et al

Title: PHOTOCURABLE RESIN COMPOSITION FOR FORMING OVERCOATS
RGB PIXELS, BLACK MATRIXES...

- Transmittal Letter Concerning 371 Filing (in duplicate)
- Certificate of Express Mailing No. EV 534640956 US
- Preliminary Amendment
- Copy of International Application Published under PCT (51 pages)
- Formal Drawings (1 sheet)
- Unexecuted Declaration for Utility or Design Patent Application;
- English Translation of Japanese Application
- Copy of International Search Report
- Information Disclosure Statement and Form PTO/SB08/A
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Title: PHOTOCURABLE RESIN COMPOSITION FOR FORMING OVERCOATS
RGB PIXELS, BLACK MATRIXES...

- Transmittal Letter Concerning 371 Filing (in duplicate)
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- Copy of International Application Published under PCT (51 pages)
- Formal Drawings (1 sheet)
- Unexecuted Declaration for Utility or Design Patent Application;
- English Translation of Japanese Application
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Attorneys

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APPLICANT: OKUO et al

APPL. SERIAL NO.: To Be Assigned

FILING DATE: Herewith

ENTITLED: PHOTOCURABLE RESIN COMPOSITION FOR
FORMING OVERCOATS RGB, BLACK MATRIXES...


CERTIFICATE OF EXPRESS MAILING

EXPRESS MAIL MAILING NUMBER: EV 534640956 US

DATE OF DEPOSIT: November 23, 2004

I hereby certify that the attached paper (along with any paper referred to as being attached or enclosed) is being deposited with the United States Postal Service "Express Mail Post Office to Addressee" Service under 37CFR 1.10 on the date indicated above and is addressed to Mail Stop: PCT, Commissioner for Patents, Box 1450, Alexandria, VA. 22313-1450

Consuelo Henry
(Name of person mailing paper)


(Signature of person mailing paper)

FORMPTO-1990 (REV. 10-2003)		U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE		ATTORNEY'S DOCKET NUMBER 37565-407800	
TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371				U.S. APPLICATION NO. (if known, see 37 CFR 1.5	
INTERNATIONAL APPLICATION NO. PCT/JP03/06339		INTERNATIONAL FILING DATE 21 May 2003		PRIORITY DATE CLAIMED 24 May 2002	
TITLE OF INVENTION PHOTOCURABLE RESIN COMPOSITION FOR FORMING OVERCOATS, RGB PIXELS, BLACK MATRIXES...					
APPLICANT(S) FOR DO/EO/US Masami OKUO et al					
Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:					
1. <input checked="" type="checkbox"/> This is a FIRST submission of items concerning a filing under 35 U.S.C. 371.					
2. <input type="checkbox"/> This is a SECOND or SUBSEQUENT submission of items concerning a filing under 35 U.S.C. 371.					
3. <input type="checkbox"/> This is an express request to begin national examination procedures (35 U.S.C. 371(f)). The submission must include items (5), (6), (9) and (21) indicated below.					
4. <input checked="" type="checkbox"/> The US has been elected (Article 31).					
5. <input checked="" type="checkbox"/> A copy of the International Application as filed (35 U.S.C. 371(c)(2))					
a. <input checked="" type="checkbox"/> is attached hereto (required only if not communicated by the International Bureau).					
b. <input type="checkbox"/> has been communicated by the International Bureau.					
c. <input type="checkbox"/> is not required, as the application was filed in the United States Receiving Office (RO/US).					
6. <input checked="" type="checkbox"/> An English language translation of the International Application as filed (35 U.S.C. 371(c)(2)).					
a. <input checked="" type="checkbox"/> is attached hereto.					
b. <input type="checkbox"/> has been previously submitted under 35 U.S.C. 154(d)(4).					
7. <input type="checkbox"/> Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371(c)(3))					
a. <input type="checkbox"/> are attached hereto (required only if not communicated by the International Bureau).					
b. <input type="checkbox"/> have been communicated by the International Bureau.					
c. <input type="checkbox"/> have not been made; however, the time limit for making such amendments has NOT expired.					
d. <input type="checkbox"/> have not been made and will not be made.					
8. <input type="checkbox"/> An English language translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371 (c)(3)).					
9. <input checked="" type="checkbox"/> An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4)).					
10. <input type="checkbox"/> An English language translation of the annexes of the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371(c)(5)).					
Items 11 to 20 below concern document(s) or information included:					
11. <input checked="" type="checkbox"/> An Information Disclosure Statement under 37 CFR 1.97 and 1.98.					
12. <input type="checkbox"/> An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.					
13. <input checked="" type="checkbox"/> A preliminary amendment.					
14. <input type="checkbox"/> An Application Data Sheet under 37 CFR 1.76.					
15. <input type="checkbox"/> A substitute specification.					
16. <input type="checkbox"/> A power of attorney and/or change of address letter.					
17. <input type="checkbox"/> A computer-readable form of the sequence listing in accordance with PCT Rule 13ter.2 and 37 CFR 1.821 - 1.825.					
18. <input type="checkbox"/> A second copy of the published international application under 35 U.S.C. 154(d)(4).					
19. <input type="checkbox"/> A second copy of the English language translation of the international application under 35 U.S.C. 154(d)(4).					
20. <input checked="" type="checkbox"/> Other items or information: Copy of Form PCT/IB/301; Copy of Form PCT/IB/304; Copy of International Search Report; Postcard; Check for \$950.00					
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U.S. APPLICATION NO. (if known, see 37 CFR 1.5)		INTERNATIONAL APPLICATION NO. PCT 03/06339		ATTORNEY'S DOCKET NUMBER 87569-407800	
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21. ☐ The following fees are submitted:

BASIC NATIONAL FEE (37 CFR 1.492 (a) (1) - (5)):
 Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2)) paid to USPTO and International Search Report not prepared by the EPO or JPO \$1080.00

International preliminary examination fee (37 CFR 1.482) not paid to USPTO but International Search Report prepared by the EPO or JPO \$920.00

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International preliminary examination fee (37 CFR 1.482) paid to USPTO but all claims did not satisfy provisions of PCT Article 33(1)-(4) \$730.00

International preliminary examination fee (37 CFR 1.482) paid to USPTO and all claims satisfied provisions of PCT Article 33(1)-(4) \$100.00

ENTER APPROPRIATE BASIC FEE AMOUNT =

Surcharge of \$130.00 for furnishing the oath or declaration later than 30 months from the earliest claimed priority date (37 CFR 1.492(c)).

CLAIMS	NUMBER FILED	NUMBER EXTRA	RATE	\$	
Total claims	17	-20 =	x \$18.00	\$	
Independent claims	1	-3 =	x \$86.00	\$	
MULTIPLE DEPENDENT CLAIM(S) (if applicable)			+ \$290.00	\$	
TOTAL OF ABOVE CALCULATIONS =				\$	950.00

☐ Applicant claims small entity status. See 37 CFR 1.27. The fees indicated above are reduced by 1/2.

SUBTOTAL =

Processing fee of \$130.00 for furnishing the English translation later than 30 months from the earliest claimed priority date (37 CFR 1.492(f)).

TOTAL NATIONAL FEE =

Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31). \$40.00 per property

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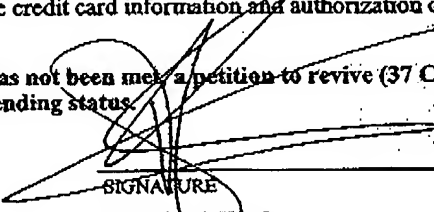
b. ☐ Please charge my Deposit Account No. _____ in the amount of \$ _____ to cover the above fees.
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d. ☐ Fees are to be charged to a credit card. **WARNING:** Information on this form may become public. Credit card information should not be included on this form. Provide credit card information and authorization on PTO-2038.

NOTE: Where an appropriate time limit under 37 CFR 1.495 has not been met, a petition to revive (37 CFR 1.137 (a) or (b)) must be filed and granted to restore the application to pending status.

SEND ALL CORRESPONDENCE TO:
 Timothy J. Keefer
 Seyfarth Shaw LLP
 55 E. Monroe Street
 Chicago, Illinois 60603
 (312) 346-8000


 SIGNATURE
 Timothy J. Keefer
 NAME
 35,567
 REGISTRATION NUMBER

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re application of:

Masami OKUO

International App. No. PCT/JP03/06339

International Filing Date: May 21, 2003

) PHOTOCURABLE RESIN COMPOSITION
) FOR FORMING OVERCOATS, RGB
) PIXELS, BLACK MATRIXES OR SPACERS
) IN COLOR FILTER PRODUCTION, AND
) COLOR FILTERS
)
)

PRELIMINARY AMENDMENT

Mail Stop: PCT
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P.O. Box 1450
Alexandria, VA 22313-1450

Dear Sir:

Applicant hereby submits the following Preliminary Amendment to the above
referenced application.

Amendments to the Specification begin on page 2 of this paper.

IN THE SPECIFICATION

Please add the attached Abstract as page 75 of the specification.

Please add the following paragraph at page 1, at the beginning of the Specification:

—This application is a U.S. National Phase of International Patent Application Serial No. PCT/JP03/06339, filed May 21, 2003 which claims priority of Japanese Patent Application Serial No. 2002-150992, filed May 24, 2002.—

Please replace paragraph 3, pages 34-35 with the following:

As the above-mentioned photocurable compound, a multifunctional polymerizable compound having two or more ethylenically unsaturated bonds may be preferably used. Particularly, a multifunctional acrylate based monomer or oligomer is preferably used, for example, there may be ethylene glycol di(meth)acrylate, diethylene glycol di(meth) acrylate, propylene glycol di(meth)acrylate, dipropylene glycol di (meth) acrylate, polyethylene glycol di(meth) acrylate, polypropylene glycol di(meth) acrylate, ~~hexanedi~~ hexanediol (meth)acrylate neoperityl glycol di(meth)acrylate, glycerol di(meth)acrylate, glycerol tri(meth)acrylate, trinethylol propane tri(meth) acrylate, 1,4—butanediol diacrylate, pentaerythritol tetra(meth) acrylate, dipentaerythritol hexa(meth)acrylate or the like. These components may be used in combination of two or more.

Please replace paragraph , pages 37-38 with the following:

As the photopolymerization initiator, a radical polymerization initiator which can be activated by ultraviolet ray, ionizing radiation, visible light or an energy beam of other wavelength, particularly an energy beam of 365 nm or less may be preferably used. The radical polymerization initiator is, for example, a compound which initiates free radical by energy of ultraviolet ray, there be benzophenone derivatives such as benzoin, benzophenone or the like or derivatives thereof such as ester, xanthone or thioxanthone derivative; halogen containing compound such as chlorosulfonyl, or chloroethyl polynuclear aromatic compound, chloromethyl heterocyclic compound, chloromethyl benzophenones or the like; triazines; fluorenones; haloalkanes; redox couples of photoreducing dye and a reducing agent; organosulfur compounds; peroxides or the like. Preferably, there may be ketone or biimidazole based compounds or the like such as Irgacure 184, Irgacure 369, Irgacure 651, Irgacure 07 (product name, manufactured by Chiba Specialty Chemicals, Inc. Darocure 1173 (product

name, manufactured by Chiba Specialty Chemicals Inc.), Adeka 1717 product name, manufactured by Asahi Denka Co., Ltd.), 2-methyl-1- (4-methylthiophenyl) -2-morpholinopropanone-1, 2,2'-bis(o-chlorophenyl)-4,5,4',5'-tetraphenyl-1,2'-biimidazole 2,2'-bis(o-chlorophenyl)-4,5,4',5'-tetraphenyl-1,2'-biimidazole (manufacture by Kurogane Kasei Co., Ltd.) or the like. These initiators may be used solely or in combination of two or more kinds. In the case of using two or more kinds together, it is better not to inhibit absorption spectral characteristics.

Please replace paragraph 2, pages 42-44 with the following:

In the photocurable resin composition of the present invention, taking preparation of the resin composition and coating property into consideration, generally, solvent which has good solubility with respect to the fumarate copolymer, the photocurable compound, the photopolymerization initiator or the like may be contained. As the solvent which can be used, for example, there may be an organic solvent such as an alcohol based solvent such as methyl alcohol, ethyl alcohol, N-propyl alcohol, n-propyl alcohol, i-propyl alcohol or the like; a Cellosolve based solvent such as methoxy ethanol, ethoxy ethanol or the like; a Carbitol based solvent such as methoxyethoxy ethanol, ethoxyethoxy ethanol or the like; an ester based solvent such as ethyl acetate, butyl acetate, methylmethoxypropionate, ethylethoxypropionate, ethyl lactate or the like; a ketone based solvent such as acetone, methylisobutylketone, cyclohexanone or the like; a Cellosolve acetate based solvent such as methoxyethyl acetate, ethoxyethyl acetate, Ethyl Cellosolve acetate or the like; a Carbitol acetate based solvent such as methoxyethoxyethyl acetate, ethoxyethoxyethyl acetate or the like; an ether based solvent such as diethyl ether, ethylene glycol dimethyl ether, diethylene glycol dimethyl ether, tetrahydrofuran or the like; an aprotic amide solvent such as N,N-dimethylformamide, N,N-dimethylacetamide, N-methylpyrrolidone or the like; a lactone based solvent such as γ -butyrolactone or the like; an unsaturated hydrocarbon based solvent such as benzene, toluene, xylene, naphthalene or the like; a saturated hydrocarbon based solvent such as N-heptane, N-hexane, N-octane, n-heptane, n-hexane, n-octane or the like. Among the solvents, the Cellosolve acetate based solvent such as methoxyethyl acetate, ethoxyethyl acetate, Ethyl Cellosolve acetate or the like; the Carbitol acetate based solvent such as methoxyethoxyethyl acetate, ethoxyethoxyethyl acetate or the like; the ether based solvent such as ethylene glycol dimethyl ether,

diethylene glycol dimethyl ether, propylene glycol diethyl ether or the like; the ester based solvent such as methyl methoxy propionate, ethyl ethoxy propionate, ethyl lactate or the like may be particularly suitably used. k preferably, MBA (3-methoxybutyl acetate, $\text{CH}_3\text{CH}(\text{OCH}_3)\text{CH}_2\text{CH}_2\text{OCOCH}_3$), PGMEA (propylene glycol monomethyl ether acetate, $\text{CH}_3\text{OCH}_2\text{CH}(\text{CH}_3)\text{OCOCH}_3$), DMDG (diethylene glycol dimethyl ether, $\text{H}_3\text{COC}_2\text{H}_4\text{OCH}_3$) or the mixture thereof may be used. Using these organic solvents, a solid content concentration is adjusted to be 5 to 50% by weight.

Please replace paragraph 2, page 53 with the following:

2,2'-bis (O-chlorophenyl) (o-chlorophenyl)-4,5,4',5'-tetraphenyl-1,2'-bimidazole: 1.0 parts by weight

DMDG: 66.0 parts by weight.

Please replace paragraph 3, page 61 with the following:

A photomask was disposed with a distance of 100 μm from the coating layer of the photocurable resin composition 1, and only a region corresponding to a region wherein a coloring layer is formed was radiated with ultraviolet ray by a proximity aligner using a 2.0 kW super high pressure mercury lamp for 10 seconds. Next, the substrate was dipped in a 0.05 wt% potassium hydroxide aqueous solution (solution temperature of 23 °C) for 1 minute to perform alkaline development, and only an uncured portion of the coating layer of the photocurable resin composition 1 was removed. After that, heat treatment was performed by leaving the substrate under atmosphere of 200 °C for 30 minutes to form a protective layer, thus, a color filter of the present invention was obtained.

Please replace Table 2, page 65 with the following Table:

	Example 1	Example 2	Comparative Example 3 <u>Example</u> 3	Comparative Example 1
Transmittance at 380 μm after heating (%)	92	90	91	75

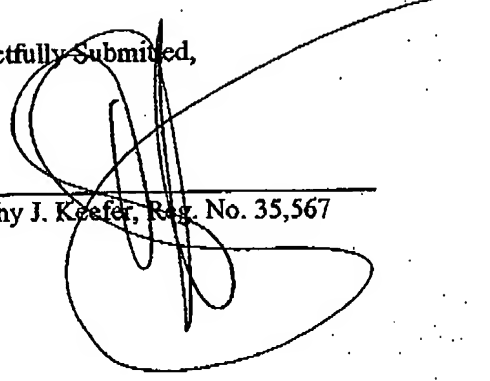
REMARKS

All of the above changes to the specification as made to correct typographical errors, no new subject matter has been added.

Date: 11/23/08

SEYFARTH SHAW LLP
55 East Monroe Street
Suite 4200
Chicago, Illinois 60603-5803
Telephone: (312) 346-8000
Facsimile: (312) 269-8869

Respectfully Submitted,



Timothy J. Keefe, Reg. No. 35,567

PTO/SB/01 (09-04)

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DECLARATION FOR UTILITY OR DESIGN PATENT APPLICATION (37 CFR 1.63)

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Submitted after Initial
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(37 CFR 1.16 (e))
required)Attorney Docket
Number

37569-407800

First Named Inventor

Masami OKUO et al

COMPLETE IF KNOWN

Application Number

Filing Date

Art Unit

Examiner Name

I hereby declare that:

Each inventor's residence, mailing address, and citizenship are as stated below next to their name.

I believe the inventor(s) named below to be the original and first inventor(s) of the subject matter which is claimed and for which a patent is sought on the invention entitled:

**PHOTOCURABLE RESIN COMPOSITION FOR FORMING OVERCOATS, RGB PIXELS,
BLACK MATRIXES OR SPACERS IN COLOR FILTER PRODUCTION, AND COLOR
FILTERS**

(Title of the Invention)

the specification of which



is attached hereto

OR



was filed on (MM/DD/YYYY)

as United States Application Number or PCT International

Application Number

and was amended on (MM/DD/YYYY)

(if applicable).

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment specifically referred to above.

I acknowledge the duty to disclose information which is material to patentability as defined in 37 CFR 1.56, including for continuation-in-part applications, material information which became available between the filing date of the prior application and the national or PCT international filing date of the continuation-in-part application.

I hereby claim foreign priority benefits under 35 U.S.C. 119(a)-(d) or (f), or 365(b) of any foreign application(s) for patent, inventor's or plant breeder's rights certificate(s), or 365(a) of any PCT international application which designated at least one country other than the United States of America, listed below and have also identified below, by checking the box, any foreign application for patent, inventor's or plant breeder's rights certificate(s), or any PCT international application having a filing date before that of the application on which priority is claimed.

Prior Foreign Application Number(s)	Country	Foreign Filing Date (MM/DD/YYYY)	Priority Not Claimed	Certified Copy Attached?	
				YES	NO
2002-150992	Japan	05/24/2002	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>
			<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
			<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
			<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>



Additional foreign application numbers are listed on a supplemental priority data sheet PTO/SB/02B attached hereto.

[Page 1 of 2]

This collection of information is required by 35 U.S.C. 115 and 37 CFR 1.63. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and 1.14. This collection is estimated to take 21 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.

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U.S. Patent and Trademark Office, U.S. DEPARTMENT OF COMMERCE

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NAME OF SOLE OR FIRST INVENTOR:		<input type="checkbox"/> A petition has been filed for this unsigned inventor		
Given Name (first and middle [if any])		Family Name or Surname		
Masami		OKUO		
Inventor's Signature			Date	
Residence: City	State	Country	Citizenship	
Mailing Address				
48-18, Futo-umenoki, Mihama-cho,				
City	State	Zip	Country	
Chita-gun	Aichi	470-2401	JAPAN	
NAME OF SECOND INVENTOR:		<input type="checkbox"/> A petition has been filed for this unsigned inventor		
Given Name (first and middle [if any])		Family Name or Surname		
Kensaku		SONODA		
Inventor's Signature			Date	
Residence: City	State	Country	Citizenship	
Mailing Address				
8, Aza, Nishimon, Taketoyo-cho				
City	State	Zip	Country	
Chita-gun	Aichi	470-2345	JAPAN	
<input checked="" type="checkbox"/> Additional inventors or a legal representative are being named on the 2 supplemental sheet(s) PTO/SB/02A or 02LR attached hereto.				

[Page 2 of 2]

PTO/SB/02A (09-04)

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DECLARATION**ADDITIONAL INVENTOR(S)**
Supplemental Sheet

Page 1 of 2

Name of Additional Joint Inventor, if any:		<input type="checkbox"/> A petition has been filed for this unsigned inventor.	
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PTO/SB/02A (09-04)

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Page 2 of 2

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Name of Additional Joint Inventor, if any:		<input type="checkbox"/> A petition has been filed for this unsigned inventor	
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Mailing Address			
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PATENT

-1-

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Patent Application of:) INFORMATION DISCLOSURE
) STATEMENT
OKUO et al)
)
Application No. To Be Assigned)
)
Filing Date: Herewith)
)
For: PHOTOCURABLE RESIN)
COMPOSITION FOR FORMING)
OVERCOATS, RGB PIXELS, BLACK))
MATRIXES OR SPACERS IN)
COLOR FILTER PRODUCTION,)
AND COLOR FILTERS)

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Sir:

Submitted herewith are patents, publications or other information [attached hereto and listed on the attached Form PTO-1449 (modified)] which may be material to the examination of this application and in respect of which there may be a duty to disclose in accordance with 37 CFR § 1.56.

This Information Disclosure Statement:

- (a) ☒ accompanies the new patent application submitted herewith. 37 CFR § 1.97(a).
- (b) ☐ is filed within three months after the filing date of the application or within three months after the date of entry of the national stage of a PCT application as set forth in 37 CFR § 1.491.
- (c) ☐ as far as is known to the undersigned, is filed before the mailing date of a first Office Action on the merits.
- (d) ☐ is filed after the first office action and more than three months after the application's filing date or PCT national stage date of entry filing but, as far as is known to the undersigned, prior to the mailing date of either a final

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-2-

rejection or a notice of allowance, whichever occurs first, and is accompanied by either the fee (\$180) set forth in 37 CFR § 1.17(p) or a certification as specified in 37 CFR § 1.97(e), as checked below.

(e) ☐ is filed after the mailing date of either a final rejection or a notice of allowance, whichever occurred first, and is accompanied by the fee (\$180) set forth in 37 CFR § 1.17(i)(1) and a certification as specified in 37 CFR § 1.97(e), as checked below. This document is to be considered as a petition requesting consideration of the information disclosure statement.

[If either of boxes (d) or (e) are checked above, the following "certification" under 37 CFR § 1.97(e) may need to be completed.] The undersigned certifies that:

(f) ☐ Each item of information contained in the information disclosure statement was cited in a communication mailed from a foreign patent office in a counterpart foreign application not more than three months prior to the filing of this information disclosure statement.

(g) ☐ No item of information contained in this information disclosure statement was cited in a communication mailed from a foreign patent office in a counterpart foreign application or, to the knowledge of the undersigned after making reasonable inquiry, was known to any individual designated in 37 CFR § 1.56(c) more than three months prior to the filing of this information disclosure statement.

A list of the patent(s) or publication(s) is set forth on the attached Form PTO-1449 (Modified).

A copy of the items on PTO-1449 (Modified) is supplied herewith:

(h) ☐ each (i) ☒ none (j) ☐ only those listed below:

Those patent(s) or publication(s) which are marked with an asterisk (*) in the attached form PTO-1449 (Modified) are not supplied because they were previously cited by or submitted to the Office in a prior application no. , filed and relied upon in this application for an earlier filing date under 35 U.S.C. § 120.

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-3-

A concise explanation of relevance of the items listed on form PTO-1449 (Modified)
is:

- (k) ☒ not given
- (l) ☐ given for each listed item
- (m) ☐ given for only non-English language listed item(s) [Required]
- (n) ☐ is in the form of an English language copy of a Search Report from a foreign patent office, issued in a counterpart application, which refers to the relevant portions of the references [copy attached].

The Examiner is reminded that a "concise explanation of the relevance" of the submitted items "may be nothing more than identification of the particular figure or paragraph of the patent or publication which has some relation to the claimed invention," MPEP § 609. The information and references disclosed in this Information Disclosure Statement may be "material" pursuant to 37 CFR § 1.56, it is not intended to constitute an admission that any patent, publication or other information referred to therein is "prior art" for this invention unless specifically designated as such.

In accordance with 37 CFR § 1.97(g), the filing of this Information Disclosure Statement shall not be construed to mean that a search has been made or that no other material information as defined in 37 CFR § 1.56(a) exists. It is submitted that the Information Disclosure Statement is in compliance with 37 CFR § 1.98 and MPEP § 609 and the Examiner is respectfully requested to consider the listed references.

Respectfully submitted,

SEYFARTH SHAW LLP

Dated: 11/27/07By: [Signature]Timothy J. Keefer
Reg. No. 35,567

Attorney for Applicant(s)

Atty. Docket No: 37569-407800

PTO/SB/08A (08-03)

Approved for use through 07/31/2006. OMB 0651-0031

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Substitute for form 1449-PTQ

INFORMATION DISCLOSURE STATEMENT BY APPLICANT

(Use as many streets as necessary)

Sheet	1	of	1
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Complete if Known

Application Number	
Filing Date	
First Named Inventor	Masami OKUO et al
Art Unit	
Examiner Name	
Attorney Docket Number	37569-407800

U. S. PATENT DOCUMENTS

[illegible]

FOREIGN PATENT DOCUMENTS

Examiner Initials*	Cite No. ¹	Foreign Patent Document	Publication Date	Name of Patentee or Applicant of Cited Document	Pages, Columns, Lines, Where Relevant Passages Or Relevant Figures Appear
		Country Code* Number * Kind Code* (if known)	MM-DD-YYYY		
		JP 2002-14468 A	01-18-02	Mitsubishi	
		JP 2001-337450 A	12-07-01	Mitsubishi	
		JP 2002-12607 A	01-15-02	Mitsubishi	

**Examiner
Signature**

Date
Considered

*EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through citation if not in conformance and not considered. Include copy of this form with need communication to applicant. ¹Applicant's unique citation designation number (optional). ²See "Kinds Codes of USPTO Patent Documents at www.uspto.gov or MPEP 801.04. ³Enter Office that issued the document, by the two-letter code (WIPO Standard ST.3). ⁴For Japanese patent documents, the indication of the year of the reign of the Emperor must precede the serial number of the patent document. ⁵Kind of document by the appropriate symbols as indicated on the document under WIPO Standard ST.16 if possible. ⁶Applicant is to place a check mark here if English language Translation is attached.

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NO. 7679 P. 3/86

1

DESCRIPTION

PHOTOCURABLE RESIN COMPOSITION FOR FORMING OVERCOATS,

RGB PIXELS, BLACK MATRIXES OR SPACERS

5 IN COLOR FILTER PRODUCTION, AND COLOR FILTERS

Technical Field

The present invention relates to a photocurable resin
10 composition containing a fumarate copolymer for forming a
protective layer, RGB pixels, a black matrix or a spacer of a
color filter, and a color filter using thereof.

Background Art

15

In recent years, a color liquid crystal display device
has rapidly been of very wide prevalence as a flat display of
personal computers or the like. Generally, as shown in FIG. 1,
a color liquid crystal display device 101 has a structure
20 comprising a color filter 1 and an electrode substrate 2 such
as a TFT substrate or the like disposed to face each other providing
a gap 3 of about 1 to 10 μm , a liquid crystal compound L filled
in the gap 3, and a sealing material 4 which seals the surrounding.
The color filter 1 has a structure comprising a black matrix layer
25 6 formed on a transparent substrate 5 in a predetermined pattern
to shield a boundary portion between pixels, a pixel part 7 in
which plural colors (generally, the three primary colors

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comprising red (R), green (G) and blue (B)) are arranged in the predetermined order to form each pixel or recently a pixel part utilizing a hologram, a protective layer 8 and a transparent electrode layer 9 laminated in this order of closest to the transparent substrate. Also, orientation layers 10 are provided in inner surface side of the color filter 1 and an electrode substrate 2 disposed to face each other. Further, pearls 11 having a given particle size are dispersed in the gap 3 as a spacer to keep a cell gap between the color filter 1 and the electrode substrate 2 constant and uniform. A color image can be obtained by controlling a light transmittance of each pixel colored in each color or a liquid crystal layer disposed behind the color filter.

The protective layer 8 formed in the color filter plays a roll of protecting the pixel part and planarizing the color filter when the pixel part is provided to the color filter. The color liquid crystal display device has a problem that if flatness of the transparent electrode layer 9 is damaged due to the presence of ununiformity of gap caused by wave on the surface of the transparent substrate of the color filter, ununiformity of gap between each pixel of R, G and B, or ununiformity of gap within each pixel or the like, mottling or contrast unevenness is caused, and as the result, the quality of image is deteriorated. Thus, the protective layer is required to be flat to a high accuracy.

In the case of dispersing the pearls 11 of particle form as shown in FIG. 1 as spacers, the pearls are dispersed at random regardless of the location behind the black matrix layer 6 or

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the pixel. If pearls are disposed on a display area, that is, the pixel part, a backlight transmits the pearl portion, the orientation of liquid crystal around pearls is disarranged, and the quality of display image is significantly deteriorated.

5 Therefore, as shown in FIG. 2, instead of dispersing pearls, a columnar spacer 12 having a height corresponding to a cell gap tends to be formed in a superimposing region with a position in inner surface side of the color filter wherein the black matrix layer 6 is formed.

10 The above-mentioned coloring layer such as the pixel part 7 or the black matrix layer 6, the protective layer 8 and the columnar spacer 12 can be formed with the use of resin. The coloring layer needs to be formed in a predetermined pattern for every pixel of each color or every line of the black matrix. Taking
15 adhesion or sealing property of a sealing portion into consideration, it is preferable that the protective layer 8 can only cover a region on a transparent substrate wherein the pixel part is formed. Further, the columnar spacer 12 is required to be accurately provided in a region in which the black matrix layer
20 is formed, that is, a non-display area. Hence, a method is proposed that a coloring layer, a protective layer and a columnar spacer are formed with the use of a photo-curable resin wherein after selectively exposing a region to be cured, the region can be subject to an alkaline development.

25 As an alkaline-soluble photo-curable resin, for example, o-cresol novolac epoxy acrylate or the like having a weight average molecular weight of about 2,000 and a carboxyl group defining

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alkaline solubility is known. However, since the resin uses a monomer component as an acryloyl group defining curability, reliability upon layer-forming is low. That is, for example, there is a risk that a residual monomer unit elutes into a liquid crystal portion or the like. Further, due to a large eluting amount upon alkaline development, layer thickness may be reduced.

As a method to introduce a radical-polymerizable group such as (meth)acryloyl group or the like to provide photo-curability into a molecular structure of a compound, for example, a method is known to prepare a reactant leaving isocyanate group(s) at terminal groups(s) by reacting diols with excess diisocyanate, and react the isocyanate group of the reactant with 2-hydroxyethyl (meth)acrylate or the like to generate urethane (meth)acrylate, thereby, introduce a radical-polymerizable group such as a (meth)acryloyl group or the like to the end. However, by this method, in principle, a (meth)acryloyl group is only introduced to both ends of the molecule. Further, there is a method to perform a radical polymerization with a multifunctional compound having two or more radical-polymerizable groups such as a (meth)acryloyl group or the like contained in one molecule. However, the content of the radical-polymerizable group cannot be controlled. Also, there are problems such as gelation or the like.

Therefore, the inventors of the present invention have proposed a photo-curable resin having a principal chain comprising at least a constituent unit represented by the following Formula 5 and a constituent unit represented by the following Formula

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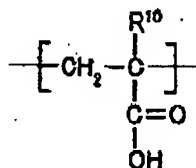
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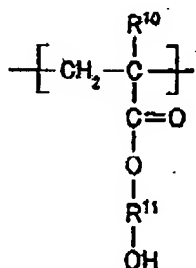
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6, and having a (meth)acryloyl oxyalkyl isocyanate compound represented by the following Formula 7 bonded to at least a part of the carboxyl group or hydroxyl group of the principal chain by the reaction of an isocyanate group of the compound (Japanese Patent Application Laid-Open (JP-A) No. 2000-105456):

Formula 5

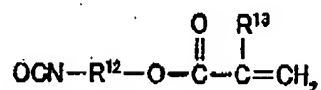


Formula 6



10

Formula 7



wherein, R¹⁰ is hydrogen atom or a C₁₋₃ alkyl group; R¹¹ is a C₂₋₄ alkylene group; R¹² is an alkylene group; R¹³ is hydrogen atom or methyl atom.

15

The proposed photo-curable resin has an advantage that it can freely adjust an amount of an alkaline-soluble carboxyl

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group and an radical-polymerizable (meth)acryloyl group.

However, all of the aforementioned various acrylic curable resins are not sufficient in thermal discoloration resistance. A color filter is exposed to high temperature while assembling a liquid crystal panel, for example, in a process of forming an orientation layer, the color filter is heated at about 250 °C for about 1 hour. In the case of forming a coloring layer or a protective layer of a color filter with the use of an acrylic curable resin, discoloration is caused during the heating process at such a high temperature, and there is a risk to cause problems such as yellowing or deterioration of transparency or the like.

In view of these circumstances, a first object of the present invention is to provide a photocurable resin composition for forming a protective layer, RGB pixels, a black matrix or a spacer of a color filter, which is excellent in thermal discoloration resistance and suitable for forming a minute structure, particularly, a photocurable resin composition having alkaline developing ability.

Also, a second object of the present invention is to provide a color filter of superior performance, which is excellent in thermal discoloration resistance or transparency and excellent in dimensional accuracy of details or evenness.

Disclosure of Invention

25

A photocurable resin composition for forming a protective layer, RGB pixels, a black matrix or a spacer of a color filter

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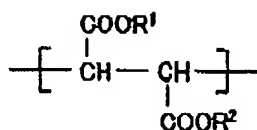
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7

of the present invention contains as a binder component a copolymer comprising at least a molecular structure in which a constituent unit represented by the following Formula 1 and a constituent unit having an acidic functional group(s) are linked:

5

Formula 1



wherein, each of R¹ and R² is independently a branched C₃₋₈ alkyl group which may be substituted, or a C₄₋₈ cycloalkyl group which may be substituted.

10

The fumarate copolymer has not only excellent thermal discoloration resistance, but can also adjust reaction curability, alkaline solubility, coatability or the like accordingly by changing a containing rate of each constituent unit. Thus, a cured product formed by the photocurable resin composition of the present invention compounding the copolymer is excellent in thermal discoloration resistance, and does not cause discoloration such as yellowing or the like or deterioration of transparency.

20

It is preferable that the constituent unit having an acidic functional group(s) in the above-mentioned fumarate copolymer is a constituent unit represented by the following Formula 2:

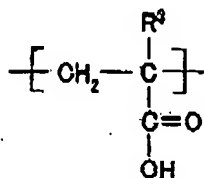
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Formula 2

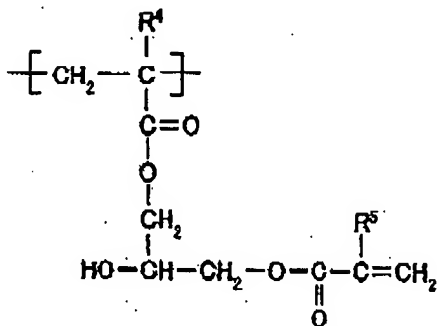


wherein, R³ is a hydrogen atom, methyl group or carboxymethyl group.

5

It is preferable that the above-mentioned fumarate copolymer is further comprised of a constituent unit with an ethylenically unsaturated bond. The ethylenically unsaturated bond contributes to reaction curability. Further, it is preferable that the constituent unit with an ethylenically unsaturated bond is a constituent unit represented by the following Formula 3 or a constituent unit represented by the following Formula 4:

15 Formula 3



wherein, R⁴ and R⁵ are respectively a hydrogen atom or methyl group;

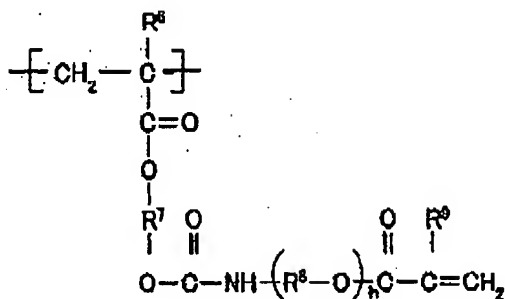
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9

Formula 4



wherein, R⁵ and R⁹ are respectively a hydrogen atom or methyl group; R⁷ is a C₂₋₄ alkylene group; R⁸ is an alkylene group; "h"

5 is 0 or 1.

It is preferable that a polymerization ratio of the constituent unit represented by the above-mentioned Formula 1 and the constituent unit having an acidic functional group(s) is adjusted to have an acid value of the copolymer as 40 to 200 mg KOH/g.

Also, if the fumarate copolymer has the ethylenically unsaturated bond containing unit together with the constituent unit represented by the Formula 1 and the constituent unit having an acidic functional group(s), it is preferable to adjust a polymerization ratio to have an acid value of the copolymer as 40 to 200 mg KOH/g and an ethylenically unsaturated bond content as 0.5 to 2.0 mmol/g.

A weight average molecular weight of the fumarate copolymer is preferably 5,000 to 100,000.

Further, if the fumarate copolymer having an ethylenically unsaturated bond is used in combination with a reaction curable

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compound, a crosslinking bond is formed between the fumarate copolymer and the reaction curable compound, thus, the reaction point density of crosslinking becomes high and the exposure sensitivity and the layer strength or hardness improve.

- 5 It is preferable that the above-mentioned photocurable resin composition for forming a protective layer, RGB pixels, a black matrix or a spacer of a color filter further contains a polymerizable compound having two or more ethylenically unsaturated bonds. Further, the photocurable resin composition
10 may further contain, if required, a photopolymerization initiator.

According to the present invention, a cured layer excellent in heat resistance can be obtained, wherein when the cured layer of the photocurable resin composition is heated at 250 °C for
15 1 hour, the light transmittance at wavelength of 380 nm of the cured layer after heating is 90% or more with respect to the light transmittance at the same wavelength of the cured layer before heating.

A photocurable resin composition for forming a protective
20 layer, RGB pixels, a black matrix or a spacer of a color filter of the present invention is suitable for forming details of the color filter, for example, a coloring layer such as a pixel part, a black matrix layer or the like, a protective layer laid on the coloring layer, and a columnar spacer for maintaining a cell gap
25 of a liquid crystal panel, and can accurately form a coloring layer and a protective layer in a desired layer thickness and a columnar spacer in a desired height.

Brief Description of Drawings

In the accompanying drawings,

FIG. 1 is a cross-sectional view schematically showing
5 an example of a liquid crystal panel; and

FIG. 2 is a cross-sectional view schematically showing
another example of a liquid crystal panel.

The sign in each figure refers to the following: 101:
liquid crystal panel, 102: liquid crystal panel, 1: a color
10 filter, 2: an electrode substrate, 3: a gap, 4: a sealing
material, 5: a transparent substrate, 6: a blackmatrix layer,
7R, 7G, 7B: a pixel part, 8: a protective layer, 9: a transparent
electrode layer, 10: an orientation layer, 11: a pearl, 12:
a columnar spacer.

15

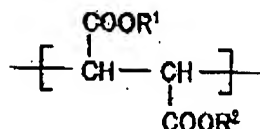
Best Mode for Carrying Out the Invention

Hereinafter, the embodiment of the present invention will
be explained in more detail. In the present invention,
20 (meth)acryl denotes an acryl group or a methacryl group, and
(meth)acryloyl denotes an acryloyl group or a methacryloyl group.

In the present invention, a copolymer (hereinafter may
be referred as "fumarate copolymer") used as a binder component
is comprised of at least a molecular structure in which a
25 constituent unit represented by the following Formula 1 and a
constituent unit having an acidic functional group(s) are linked:

12

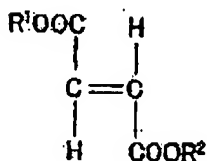
Formula 1



wherein, each of R¹ and R² is independently a branched C₃₋₈ alkyl group which may be substituted, or a C₄₋₈ cycloalkyl group which may be substituted.

The constituent unit represented by the Formula 1 (fumarate unit) is a component mainly contributes to the thermal discoloration resistance and transparency of a resin. As a monomer used for introducing the constituent unit represented by the Formula 1 to a principal chain of the copolymer, a fumarate represented by the following Formula 8 can be used:

Formula 8



wherein, R¹ and R² are as same as the Formula 1.

As examples of a functional group in which R¹ and R² in the Formula 1 and the Formula 8 are respectively a branched C₃₋₈ alkyl group which may be substituted, there may be an isopropyl group, a 1-chloro-2-propyl group, a 1,3-dichloro-2-propyl group, a sec-butyl group, a 3-chloro-2-butyl group, a tert-butyl group,

a sec-amyl group, a 3-pentyl group, a 2,3-dimethyl-3-pentyl group, a tert-amyl group, a neopentyl group, an isopentyl group, a 4-methyl-2-pentyl group, a 2-ethyl-hexyl group or the like.

As examples of a fumarate having such a branched alkyl group and/or a substituted branched alkyl group, there may be diisopropyl fumarate, di-sec-butyl fumarate, di-tert-butyl fumarate, diisobutyl fumarate, di-sec-amyl fumarate, di-tert-amyl fumarate, di-4-methyl-2-pentyl fumarate, di-sec-amyl fumarate, di-3-pentyl fumarate, bis(2,4-dimethyl-3-pentyl) fumarate, isopropyl-sec-butyl fumarate, tert-butyl-4-methyl-2-pentyl fumarate, isopropyl-tert-butyl fumarate, sec-butyl-tert-butyl fumarate, sec-butyl-tert-amyl fumarate, di-4-methyl-pentyl fumarate, tert-butyl-isoamyl fumarate or the like.

As examples of a functional group wherein R^1 and R^2 in the Formula 1 and the Formula 8 are respectively a C_{4-8} cycloalkyl group which may be substituted, there may be a cyclobutyl group, a cyclopentyl group, a cyclohexyl group, a cycloheptyl group, a 4-chloro-cyclohexyl group, a 4-tert-butyl-cyclohexyl group, an isobornyl group, a bornyl group, a norbornyl group or the like.

As examples of a fumarate having such a cycloalkyl group and/or a substituted cycloalkyl group, there may be dicyclobutyl fumarate, dicyclopentyl fumarate, dicyclohexyl fumarate, dicycloheptyl fumarate, dicyclooctyl fumarate, bis(4-chloro-cyclohexyl) fumarate, bis(4-tert-butyl-cyclohexyl) fumarate, diisobornyl fumarate, dibornyl fumarate, dinorbornyl fumarate or the like.

As examples of a fumarate wherein R¹ is an alkyl group and R² is a cycloalkyl group in the Formula 1, there may be isopropyl-cyclobutyl fumarate, 1-chloro-2-propylcyclopentyl fumarate, 1,3-dichloro-2-propyl-cyclohexyl fumarate, 5 sec-butyl-cyclohexyl fumarate, 3-chloro-2-butyl-cyclohexyl fumarate, tert-butyl-cyclopentyl fumarate, tert-butylcyclohexyl fumarate, sec-amyl-cyclohexyl fumarate, 3-pentyl-bornyl fumarate, 2,3-dimethyl-3-pentyl adamantyl fumarate, tert-amyl-cyclohexyl fumarate, neopentyl-cyclopentyl fumarate, 4-methyl 10 -2-pentyl-cyclohexyl fumarate, 2-ethyl-hexylcyclohexyl fumarate or the like.

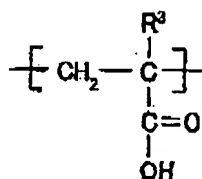
Among the above fumarate, diisopropyl fumarate, di-sec-butyl fumarate, di-tert-butyl fumarate, dicyclohexyl fumarate, and di-tert-amyl fumarate are preferable.

15 The constituent unit having an acidic functional group(s) (acidic functional group containing unit) is a component which contributes to alkaline developing ability. The containing rate is adjusted according to the degree of alkaline solubility required for a resin. As a monomer used for introducing the 20 constituent unit having an acidic functional group(s) to the principal chain of the copolymer, a compound having an ethylenically unsaturated bond and an acidic functional group can be used. The acidic functional group is generally a carboxyl group, however, it may be a component other than a carboxyl group 25 if it contributes to alkaline developing ability.

As the constituent unit having an acidic functional group(s), a constituent unit represented by the following Formula

2 is preferable:

Formula 2



5 wherein, R^3 is a hydrogen atom, methyl group or carboxymethyl group.

As a monomer used for introducing the constituent unit of the Formula 2, acrylic acid, methacrylic acid or itaconic acid
10 can be used.

A copolymer used in the present invention contains the constituent unit represented by the Formula 1 (fumarate unit) and the constituent unit having an acidic functional group(s) (acidic functional group containing unit) as requisite principal
15 chain constituting components, however, other copolymerization component may be contained in the principal chain. In the principal chain, for example, a constituent unit having an ethylenically unsaturated bond, a constituent unit having aromatic carbocycle and/or a constituent unit having an ester
20 group may be contained.

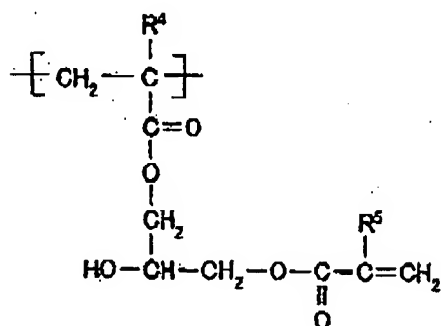
The constituent unit having an ethylenically unsaturated bond (ethylenically unsaturated bond containing unit) is a component which contributes to reaction curability of a resin. The containing rate is adjusted according to the degree of required

curability. The ethylenically unsaturated bond which contributes to curability can be copolymerized together under the polymerization condition to form a principal chain linkage, thus, after forming a principal chain portion of a copolymer, 5 The ethylenically unsaturated bond is introduced via an appropriate functional group to the principal chain of the copolymer in a pendant shape.

As the ethylenically unsaturated bond containing unit, the following Formula 3 is preferable:

10

Formula 3



wherein, R⁴ and R⁵ are respectively a hydrogen atom or a methyl group.

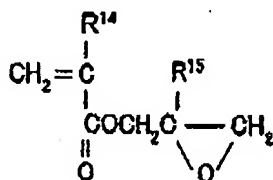
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In order to introduce the constituent unit of the Formula 3 to the copolymer, firstly, fumarate and (meth)acrylic acid or itaconic acid are copolymerized to form a principal chain portion of the copolymer. After that, epoxy group containing 20 (meth)acrylate may be reacted with a carboxyl group derived from the above-mentioned (meth)acrylic acid or itaconic acid. It is,

however, necessary to adjust the amount of the epoxy group containing (meth)acrylate appropriately since if the amount of the carboxyl group derived from (meth)acrylic acid or itaconic acid becomes too small, the alkaline developing ability becomes
5 insufficient.

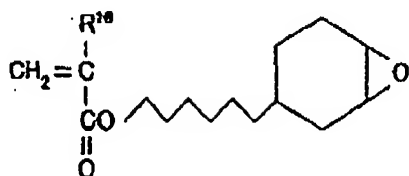
As the epoxy group containing (meth)acrylate, glycidyl or methylglycidyl (meth)acrylate represented by the following Formula 9, or an alicyclic epoxy compound represented by the following Formula 10 may be exemplified. As glycidyl
10 methacrylate of the Formula 9, BLEMER GH (product name, manufactured by NOF Corporation), and as methylglycidyl methacrylate, CYCLOMER M-GMA (product name, manufactured by DAICEL CHEMICAL INDUSTRIES, LTD.) are commercially available. As alicyclic epoxy compound of the Formula 10, CYCLOMER M100 and
15 CYCLOMER A200 (product name, manufactured by DAICEL CHEMICAL INDUSTRIES, LTD.) is commercially available:

Formula 9



20 wherein, each of R¹⁴ and R¹⁵ is independently a hydrogen atom or a methyl group;

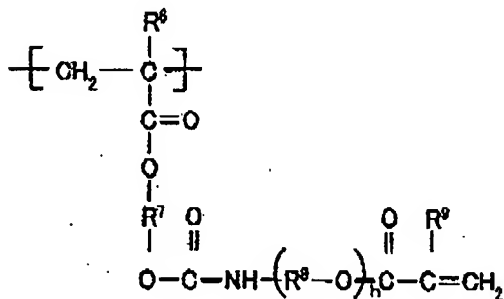
Formula 10



wherein, R¹⁶ is a hydrogen atom or a methyl group; in CYCLOMER M100, R¹⁶ is a methyl group; in CYCLOMER A200, R¹⁶ is a hydrogen atom.

Also, As the ethylenically unsaturated bond containing unit, a constituent unit represented by the following Formula 4 is preferable:

Formula 4



wherein, R⁶ and R⁹ are independently a hydrogen atom or a methyl group; R⁷ is a C₂₋₄ alkylene group; R⁸ is an alkylene group; "h" is 0 or 1.

R⁷ contained in the Formula 4 is a C₂₋₆ alkylene group, for example, an ethylene group, a propylene group, a butylene group or the like can be exemplified. R⁸ is preferably a C₂₋₆ alkylene

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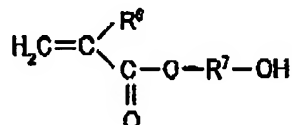
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group.

In order to introduce the constituent unit of the Formula 4 to the copolymer, firstly, together with fumarate and (meth)acrylic acid or itaconic acid, hydroxyalkyl (meth)acrylate represented by the following Formula 11 is copolymerized to form a principal chain portion of the copolymer:

Formula 11

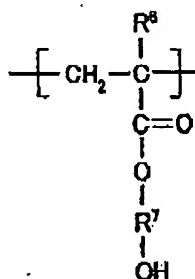


10 wherein, R⁶ and R⁷ are as same as the Formula 4.

As hydroxyalkyl (meth)acrylate of the Formula 11, 2-hydroxyethyl acrylate, 2-hydroxyethyl methacrylate, 2-hydroxypropyl acrylate, 2-hydroxypropyl methacrylate, 15 4-hydroxybutyl acrylate, 4-hydroxybutyl methacrylate or the like may be exemplified.

By copolymerizing the hydroxyalkyl (meth)acrylate, a constituent unit represented by the following Formula 12 having a hydroxyl group is introduced into the principal chain of the 20 copolymer:

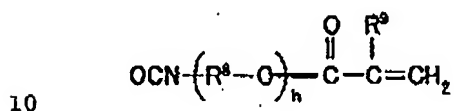
Formula 12



wherein, R⁶ and R⁷ are as same as the Formula 4.

- 5 After that, an isocyanate compound represented by the following Formula 13 may be reacted to the hydroxyl group derived from the above-mentioned hydroxyalkyl (meth)acrylate:

Formula 13



wherein, R⁸ is an alkylene group; R⁹ is a hydrogen atom or a methyl group; "h" is 0 or 1.

- As the (meth)acryloyloxyalkyl isocyanate of the Formula
- 15 13, methacryloyl isocyanate, 2-acryloyloxyethyl isocyanate, 2-methacryloylethyl isocyanate or the like may be exemplified. Among them, it is preferable to use a compound wherein a (meth)acryloyl group is bonded with an isocyanate group(-NCO) via a C₂₋₆ alkylene group, for example, 2-acryloyloxyethyl
- 20 isocyanate, 2-methacryloylethyl isocyanate or the like. Among

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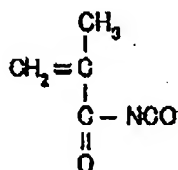
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them, methacryloyl isocyanate is represented by the following Formula 14, which is commercially available, for example, in the product name of "MAI" manufactured by NIPPON PAINT Co., Ltd. or the like. Also, 2-methacryloylethyl isocyanate is commercially available, for example, in the product name of "Karencz MOI" manufactured by SHOWA DENKO K.K. or the like:

Formula 14



10

In the above-mentioned example, a portion introducing the constituent unit having an ethylenically unsaturated bond to the copolymer is a principal chain constituent unit derived from a monomer having a hydroxyl group or carboxyl group. It is also possible, adversely, to utilize a principal chain constituent unit derived from a monomer having an isocyanate group or epoxy group as an introducing portion.

For example, the above-mentioned methacryloyl isocyanate represented by the Formula 14, the above-mentioned glycidyl (meth)acrylate represented by the Formula 9, the above-mentioned alicyclic epoxy compound represented by the Formula 10 or the like can be used. They are, similarly to the previously exemplified monomer, easy to control reaction or produce. After forming a principal chain portion of a copolymer using these

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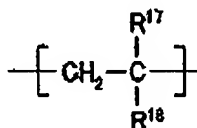
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monomers, by reacting a compound having a functional group which can react with an isocyanate group or epoxy group introduced to the principal chain portion (hydroxyl group or carboxyl group) and having an ethylenically unsaturated bond with the principal
5 chain portion, a constituent unit having an ethylenically unsaturated bond can be introduced.

The constituent unit having an aromatic carbocycle (aromatic carbocycle containing unit) is a component which provides coatability to the resin when the copolymer is used as
10 a coating layer forming resin for a protective layer of a color filter or the like. As a monomer used to introduce the aromatic carbocycle containing unit to the principal chain of the copolymer, a compound having an ethylenically unsaturated bond and aromatic carbocycle can be used.

15 As the aromatic carbocycle containing unit, a constituent unit represented by the following Formula 15 is preferable:

Formula 15



20 wherein, R¹⁷ represents a hydrogen atom or methyl group; R¹⁸ represents an aromatic carbocycle.

R¹⁸ in the above-mentioned formula is an aromatic carbocycle, for example, a phenyl group, a naphthyl group or the like may
25 be exemplified. As a monomer used to introduce the constituent

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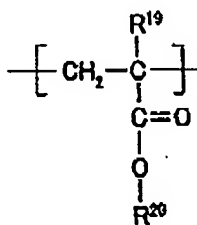
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unit, for example, styrene and α -methylstyrene may be exemplified, the aromatic ring of which may be substituted by a halogen atom such as chlorine, bromine or the like, an alkyl group such as a methyl group, an ethyl group or the like, an amino group such as an amino group, a dialkylamino group or the like, a cyano group, a carboxyl group, a sulfonic acid group, a phosphoric acid group or the like.

As the constituent unit having an ester group (ester group containing unit) is a component which inhibits alkaline developing ability of the resin. As a monomer used to introduce the ester group containing unit to the principal chain of the copolymer, a compound having an ethylenically unsaturated bond and an ester group can be used.

As the ester group containing unit, the following Formula 16 is preferable:

Formula 16



wherein, R^{19} represents a hydrogen atom or a methyl group; R^{20} represents an alkyl group or an aralkyl group.

R^{20} in the above-mentioned formula is an alkyl group or an aralkyl group, for example, an aralkyl group such as a C_{1-12}

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alkyl group, a benzyl group, a phenylethyl group or the like may be exemplified. As a monomer used to introduce the constituent unit, for example, esters of (meth)acrylic acid such as methyl (meth)acrylate, ethyl (meth)acrylate, butyl (meth)acrylate, 5 2-ethylhexyl (meth)acrylate, phenyl (meth)acrylate, cyclohexyl (meth)acrylate, dicyclopentanyl (meth)acrylate, dicyclopentanyloxyethyl (meth)acrylate, isobornyl (meth)acrylate, benzyl (meth)acrylate, phenylethyl (meth)acrylate or the like may be exemplified.

10 As the monomer used to introduce each constituent unit to the principal chain of the copolymer, the monomer exemplified for each constituent unit may be used solely or in a mixture of two or more kinds.

As a particularly preferable copolymer, there may be a 15 copolymer having reaction curability (curable resin) wherein the constituent unit having the ethylenically unsaturated bond is linked with the constituent unit represented by the Formula 1 and the constituent unit having an acidic functional group(s), specifically, a random copolymer or a block copolymer represented 20 by the following Formula 17 or the following Formula 18, particularly, a random copolymer. The principal chain of these copolymers may contain other principal chain constituent units, if required:

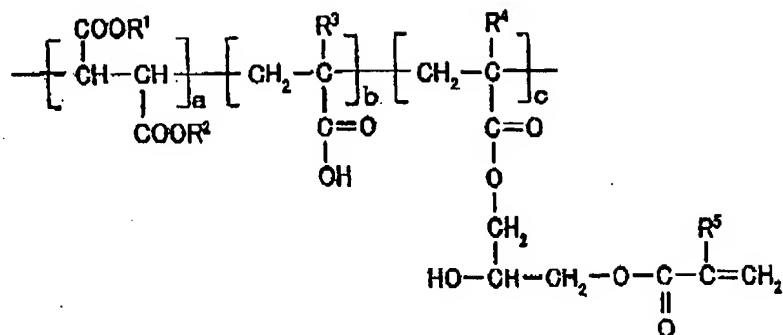
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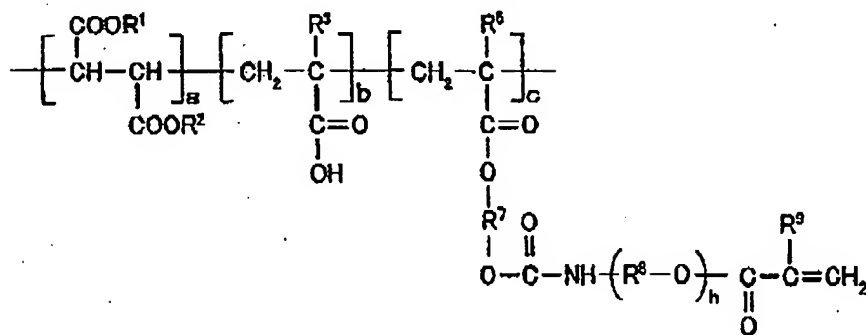
Formula 17



wherein, any of R^1 to R^5 is as same as the above; each of "a", "b", "c" is an integer;

5

Formula 18



wherein, any of R^1 to R^3 , any of R^6 to R^9 and "h" are as same as the above; each of "a", "b", "c" is an integer.

10

In the present invention, a containing rate of each constituent unit comprising a molecular structure of a copolymer may be accordingly adjusted. If a containing rate of the constituent unit represented by the Formula 1 is too small, thermal discoloration resistance may not sufficiently improve, and if

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the containing rate is too large, there is a problem that alkaline developing ability may deteriorate. Further, if the amount of the acidic functional group containing unit is too small, the alkaline developing ability may become insufficient, and if the amount is too large, there is a problem that solvent solubility may deteriorate. Also, if the amount of the ethylenically unsaturated bond is too small, reaction curability may become insufficient, and if the amount is too large, there is a problem that substrate adhesion may deteriorate.

Specifically, a polymerization ratio is adjusted so that the above-mentioned fumarate copolymer contains the constituent unit represented by the Formula 1 and the constituent unit having an acidic functional group(s), and an acid value is preferably 40 to 200 mgKOH/g, more preferably, 70 to 150 mgKOH/g.

In the case that a fumarate copolymer has the ethylenically unsaturated bond containing unit together with the constituent unit represented by the Formula 1 and the constituent unit having an acidic functional group(s), the polymerization ratio is adjusted so that the acid value is preferably 40 to 200 mgKOH/g, more preferably 70 to 150 mgKOH/g, and an ethylenically unsaturated bond content is preferably 0.5 to 2.0 mmol/g, more preferably, 0.8 to 1.6 mmol/g.

In order to produce the above-mentioned fumarate copolymer, firstly, a polymer (raw material polymer) comprising a principal chain containing the constituent unit represented by the Formula 1 and the constituent unit having an acidic functional group(s) represented by the Formula 2, and further if required, a

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constituent unit having a functional group which can later introduce a pendant structure having an ethylenically unsaturated bond, a constituent unit having an aromatic carbocycle represented by the Formula 15, a constituent unit having an ester group represented by the Formula 16 or other constituent units is produced. After that, the raw material polymer may be reacted with a compound having an ethylenically unsaturated bond and other functional group to introduce the pendant structure of an ethylenically unsaturated bond.

10 However, in the case that an acidic functional group containing unit also functions as a pendant bond portion of an ethylenically unsaturated bond such as the case that a constituent unit having a carboxyl group represented by the Formula 2 is used as an acidic functional group containing unit and glycidyl
15 (meth)acrylate is used as an ethylenically unsaturated bond containing unit, a principal chain of the raw material polymer may not need to contain a constituent unit having a functional group necessary to introduce the ethylenically unsaturated bond later besides the acidic functional group containing unit.

20 As a solvent for polymerization used to produce the raw material polymer, a solvent not having active hydrogen such as a hydroxyl group, amino group or the like is preferable, for example, ethers such as tetrahydrofuran or the like; glycol ethers such as diethylene glycol dimethyl ether, diethylene glycol diethyl
25 ether, diethylene glycol methylethyl ether or the like; Cellosolve esters such as Methyl Cellosolve acetate or the like; propylene glycol monomethyl ether acetate, 3-methoxybutyl acetate or the

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likemaybeexemplified, andalso, aromatichydrocarbons, ketones, esters or the like may be used.

As a photopolymerization initiator used to produce the raw material polymer, generally known radical polymerization
5 initiators may be used. The examples are nitrile based azo compounds (nitrile based azo based polymerization initiators) such as 2,2'-azobisisobutyronitrile, 2,2'-azobis-(2,4-dimethyl valeronitrile), 2,2'-azobis-(4-methoxy-2,4-dimethyl
10 (non-nitrile based azo based polymerization initiators) such as dimethyl-2,2'-azobis(2-methylpropionate), 2,2'-azobis(2,4,4-trimethylpentane) or the like; organic peroxides (peroxide based polymerization initiator) such as t-hexylperoxy pivalate, tert-butylperoxy pivalate, 3,5,5-trimethylhexanoyl peroxide,
15 octanoyl peroxide, lauroyl peroxide, stearoyl peroxide, 1,1,3,3-tetramethylbutylperoxy-2-ethylhexanoate, succinic peroxide, 2,5-dimethyl-2,5-di(2-ethylhexanoylperoxy)hexane, 1-cyclohexyl-1-methylethylperoxy-2-ethylhexanoate, t-hexylperoxy-2-ethylhexanoate, 4-methylbenzoyl peroxide,
20 benzoyl peroxide, 1,1'-bis-(tert-butylperoxy)cyclohexane or the like; or hydrogen peroxide. In the case of using peroxide as the radical polymerization initiator, it may be used in combination with a reducing agent as a redox type photopolymerization initiator.

25 In producing the raw material polymer, a chain-transfer agent may be used to adjust a weight average molecular weight, for example, there may be halogenated hydrocarbons such as

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chloroform, carbon tetrabromide or the like; mercaptans such as
n-hexyl mercaptan, n-octyl mercaptan, n-dodecyl mercaptan,
tert-dodecyl mercaptan, thioglycolic acid or the like; xanthogen
such as dimethyl xanthic disulfide, diisopropyl xanthic disulfide
5 or the like; terpinolene, α -methylstyrene dimer or the like.

The raw material polymer may be a random copolymer or a
block copolymer. When producing the random copolymer, a
compounding composition containing each monomer deriving each
constituent unit, a catalyst or the like is dropped to a
10 polymerization vessel containing a solvent with a temperature
condition of 80 to 110 °C for 2 to 5 hours, and is subject to
maturing to polymerize.

A polystyrene calibrated-weight average molecular weight
(hereinafter, simply referred as "weight average molecular
15 weight" or "MW") of the raw material polymer is preferably 5,000
to 100,000, more preferably the raw material polymer has an acid
value of 40 mgKOH/g to 200 mgKOH/g and a hydroxyl group value
of 5 mgKOH/g to 400 mgKOH/g.

The reaction to introduce the ethylenically unsaturated
20 bond to the raw material polymer varies according to the
combination of a molecular structure of the raw material polymer
and a molecular structure of a unit which introduces the
ethylenically unsaturated bond.

In the case of reacting a raw material polymer comprising
25 the constituent unit represented by the Formula 1 and the carboxyl
group containing unit represented by the Formula 2 and further
containing other constituent units if required with glycidyl

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(meth)acrylate as an introducing unit of an ethylenically unsaturated bond, by pouring all amount of the glycidyl (meth)acrylate at a time in a solution of the raw material polymer and continue to react for a constant time under the presence of
5 a small amount of catalyst or by dropping thereof little by little, the copolymer represented by the Formula 17 can be obtained.

Further, in the case of reacting a raw material polymer comprising the constituent unit represented by the Formula 1, the carboxyl group containing unit represented by the Formula
10 2 and the hydroxyl group containing unit represented by the Formula 12, and further contains other constituent units if required with the isocyanate compound represented by the Formula 13 as an introducing unit of the ethylenically unsaturated bond, by pouring all amount of the isocyanate compound at a time in a solution
15 of the raw material polymer and continue to react for a constant time under the presence of a small amount of catalyst or by dropping thereof little by little, the copolymer represented by the Formula 18 can be obtained. In this case, as the catalyst, dibutyl tin laurate or the like may be used. Also, if required, a
20 polymerization inhibitor such as p-methoxyphenol, hydroquinone, naphthylamine, tert-butylcatechol, 2,3-di-tert-butyl-p-cresol or the like may be used.

The isocyanate compound having an ethylenically unsaturated bond performs addition reaction via an isocyanate
25 group with respect to an alcoholic hydroxyl group of the raw material polymer to form an urethane bond. As the result, the ethylenically unsaturated bond is introduced to the hydroxyl group

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containing unit portion represented by the Formula 12 of the principal chain of the raw material polymer to form the constituent unit of the Formula 4.

Further, the isocyanate compound having an ethylenically unsaturated bond performs condensation reaction accompanying elimination of carbonic acid gas via an isocyanate group with respect to a carboxyl group of the raw material polymer to form an amide bond. As the result, the ethylenically unsaturated bond is introduced to a portion in the carboxyl group containing unit represented by the Formula 2 of the principal chain of the raw material polymer. However, the reactivity of the isocyanate compound with respect to the carboxyl group is significantly small in comparison with the reactivity of the isocyanate compound with respect to the alcoholic hydroxyl group. Hence, the ethylenically unsaturated bond is mainly introduced to an alcoholic hydroxyl group containing unit portion, and the amount of an ethylenically unsaturated bond introduced to a portion in the carboxyl group containing unit is generally significantly small. Therefore, most of the carboxyl groups are left and the alkaline developing ability is not lost.

In the case of using thus obtained fumarate copolymer for forming a coloring layer, a protective layer laid on the coloring layer or a columnar spacer for maintaining a cell gap of a liquid crystal panel of a color filter, it is preferable to adjust the polystyrene calibrated-weight average molecular weight measured by GPC (gel-permeation chromatography) to be 5,000 to 100,000, more preferably 8,000 to 70,000. If the weight average molecular

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weight is smaller than 5,000, the developing ability is too good so that it is hard to control a pattern form upon pattern exposure. Even if a pattern can be formed, there is a problem that a final layer thickness decreases (decrease of the layer thickness) or the like. On the other hand, if the weight average molecular weight is larger than 100,000, there is a problem that the viscosity when a resist layer of a photocurable resin is formed becomes too high so as to deteriorate coatability, the developing ability deteriorates so that it becomes hard to form a pattern or the like.

An acid value of the fumarate copolymer is preferably 40 mgKOH/g to 200 mgKOH/g, more preferably 70 mgKOH/g to 150 mgKOH/g. An acid value is related to the alkaline developing ability. If the acid value is too low, the developing ability deteriorates and causes problems such as residue formation or the like. On the other hand, if the acid value is too high, the developing ability becomes too good so that there is a problem that it is hard to control a pattern form upon pattern exposure or the like. A hydroxyl group value of a fumarate copolymer can be adjusted in the range of 5 mgKOH/g to 400 mgKOH/g.

The fumarate copolymer used in the present invention is comprised by linkage of the constituent unit of the Formula 1 which contributes to thermal discoloration resistance and the acidic functional group containing unit which contributes to acidity or alkaline solubility, further if required, the ethylenically unsaturated bond containing unit which contributes to reaction curability, the aromatic carbocycle containing unit

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which contributes to coatability, or the ester group containing unit which inhibits alkaline developing ability, wherein the fumarate copolymer is not only excellent in thermal discoloration resistance but is also capable of accordingly adjust the reaction curability, the alkaline solubility, the coatability or the like by changing the containing rate of each constituent unit.

Hence, the above-mentioned fumarate copolymer can be suitably used as a binder component of a photocurable resin composition capable of alkaline development for forming a protective layer, RGB pixels, a black matrix or a spacer of a color filter. The photocurable resin composition using the fumarate copolymer is suitable for forming details of a color filter, particularly, a coloring layer, a protective layer or a columnar spacer for maintaining a cell gap of a liquid crystal panel of a color filter. The photocurable resin composition is excellent in thermal discoloration resistance and yellowing is hardly caused, therefore, the photocurable resin composition is significantly suitable for forming a portion which requires high transparency such as a pixel part, a protective layer or the like.

Hereinafter, a photocurable resin composition compounding a fumarate copolymer for forming a protective layer, RGB pixels, a black matrix or a spacer of a color filter will be explained in detail.

By compounding a photocurable compound, a photopolymerization initiator, a sensitization agent or the like to a fumarate copolymer, if required, a photocurable resin composition capable of alkaline development can be prepared. In

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the case of a fumarate copolymer having an ethylenically unsaturated bond containing unit, an ethylenically unsaturated bond can form a crosslinking bond by light radiation, thus, the fumarate copolymer can be used as a photocurable resin composition without compounding a photocurable compound. Even in that case, in order to improve reactivity or the cross-linking density, it is preferable to compound the photocurable compound.

In the present invention, the fumarate copolymer is contained in the photocurable resin composition in ratio of the solid content generally by 5 to 80 % by weight, preferably 10 to 50 % by weight. If a content of the fumarate copolymer exceeds 80 % by weight, viscosity becomes too high, as the result, flowability deteriorates and applicability may decrease. If the content of the fumarate copolymer lowers 5 % by weight, the viscosity becomes too low, as the result, coating layer stability after coating and drying is insufficient, and there may be problems such as exposure failure, deterioration of developing suitability or the like.

As the above-mentioned photocurable compound, a multifunctional polymerizable compound having two or more ethylenically unsaturated bonds may be preferably used. Particularly, a multifunctional acrylate based monomer or oligomer is preferably used, for example, there may be ethylene glycol di(meth)acrylate, diethylene glycol di(meth)acrylate, propylene glycol di(meth)acrylate, dipropylene glycol di(meth)acrylate, polyethylene glycol di(meth)acrylate, polypropylene glycol di(meth)acrylate, hexane di(meth)acrylate,

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neopentyl glycol di(meth)acrylate, glycerol di(meth)acrylate, glycerol tri(meth)acrylate, trimethylol propane tri(meth)acrylate, 1,4-butanediol diacrylate, pentaerythritol (meth)acrylate, dipentaerythritol hexa(meth)acrylate or the like.

5 These components may be used in combination of two or more.

The above-mentioned multifunctional polymerizable compound preferably contains a monomer having three or more ethylenically unsaturated bonds, the content of which is preferably about 30 to 95 % by weight of the amount of the
10 multifunctional polymerizable compound used.

Further, a monofunctional monomer such as methyl (meth)acrylate, ethyl (meth)acrylate, propyl(meth)acrylate, butyl (meth)acrylate, pentyl (meth)acrylate, ethyl hexyl (meth)acrylate, styrene, methylstyrene, N-vinylpyrrolidone or
15 the like may be added to the multifunctional polymerizable compound as a reactive diluent.

The multifunctional polymerizable compound may be contained in a photocurable resin composition by 3 to 80 % by weight in ratio of the solid content, preferably 5 to 75 % by
20 weight. If the amount of the multifunctional polymerizable compound becomes less than 3 % by weight, inconvenience may be caused that various physical strength such as adhesion, heat resistance or the like of a formed layer becomes insufficient. If the value exceeds 80 % by weight, inconvenience may be caused
25 that stability of the photocurable resin composition deteriorates and also flexibility of a formed layer may become insufficient. Further, in order to improve solubility with respect to developing

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5 resolution, this proportion is necessary. In the case of outside the above-mentioned range, though a pattern resolution will be performed, a monomer curing rate becomes high, and scum or feathering may be caused around pattern. Further in the case of outside the above-mentioned range, if worse, an immigration of the resist due to partial swelling or peeling may be caused, and an accurate pattern forming may be inhibited.

Further in a photocurable resin composition of the present invention, if required, a compound having two or more epoxy groups in the molecular (epoxy resin) may be compounded in order to improve heat resistance, adhesion, chemical resistance (particularly, alkaline resistance). As the epoxy resin, for example, there may be a bisphenol A type epoxy resin such as Epikote 1001, 1002, 1003, 1004, 1007, 1009, 1010 (product name, manufactured by Japan Epoxy Resins Co., Ltd.) or the like; a bisphenol F type epoxy resin such as Epikote 807 (product name, manufactured by Japan Epoxy Resins Co., Ltd.) or the like; a phenol novolac type epoxy resin such as EPPN 201, 202 (product name, manufactured by NIPPON KAYAKU CO., LTD.), Epikote 154 (product name, manufactured by Japan Epoxy Resins Co., Ltd) or the like; a cresol novolac type epoxy resin such as EOCN 102, 103S, 104S, 1020, 1025, 1027 (product name, manufactured by NIPPON KAYAKU CO., LTD.), Epikote 180S (product name, manufactured by Japan Epoxy Resins Co., Ltd.) or the like. Also, a cyclic aliphatic epoxy resin or aliphatic polyglycidyl ether may be exemplified.

Among them, the bisphenol A type epoxy resin, the bisphenol F type epoxy resin, the phenol novolac type epoxy resin, and the

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cresol novolac type epoxy resin are preferable. Most of these compounds having two or more epoxy groups in the molecular have high molecular weight, however, glycidyl ether of bisphenol A or bisphenol F has low molecular weight. Such a low molecular weight epoxy resin is particularly preferable. Also, an acrylic copolymer or the like containing glycidyl (meth)acrylate, oxetane (meth)acrylate, alicyclic epoxy (meth)acrylate or the like in the resin skeleton is effective.

In the case of compounding such an epoxy resin in the photocurable resin composition, the epoxy resin may be contained in ratio of the solid content generally by 60 % by weight or less, preferably 5 to 40 % by weight. If the content of the epoxy resin exceeds 60 % by weight, the amount of epoxy resin becomes too large and the storage stability or the developing suitability of the photocurable resin composition may be deteriorated. Further, the epoxy resin is also effective to remove tack of dried coating layer of the photocurable resin composition, and exhibits sufficient effect with an adding amount of about 5 % by weight. The epoxy resin reacts with an acid group left unreacted after exposure and alkaline development in the coating layer by heat treatment to provide excellent alkaline resistance to the coating layer.

As the photopolymerization initiator, a radical polymerization initiator which can be activated by ultraviolet ray, ionizing radiation, visible light or an energy beam of other wavelength, particularly an energy beam of 365 nm or less may be preferably used. The radical polymerization initiator is,

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for example, a compound which initiates free radical by energy of ultraviolet ray, there may be benzophenone derivatives such as benzoin, benzophenone or the like or derivatives thereof such as ester; xanthone or thioxanthone derivative; halogen containing compound such as chlorosulfonyl, or chloromethyl polynuclear aromatic compound, chloromethyl heterocyclic compound, chloromethyl benzophenones or the like; triazines; fluorenones; haloalkanes; redox couples of photoreducing dye and a reducing agent; organosulfur compounds; peroxides or the like. Preferably, there may be ketone or biimidazole based compounds or the like such as Irgacure 184, Irgacure 369, Irgacure 651, Irgacure 907 (product name, manufactured by Chiba Specialty Chemicals, Inc.), Darocure 1173 (product name, manufactured by Chiba Specialty Chemicals, Inc.), Adeka 1717 (product name, manufactured by Asahi Denka Co., Ltd.), 2-methyl-1-(4-methylthiophenyl)-2-morpholinopropanone-1, 2,2'-bis(o-chlorophenyl)-4,5,4'-tetraphenyl-1,2'-biimidazole (manufacture by Kurogane Kasei Co., Ltd.) or the like. These initiators may be used solely or in combination of two or more kinds. In the case of using two or more kinds together, it is better not to inhibit absorption spectral characteristics.

The radical polymerization initiator may be contained in the photocurable resin composition in ratio of the solid content generally by 0.05 to 18 % by weight, preferably 0.1 to 13 % by weight. If an adding amount of the radical polymerization initiator lowers 0.05 % by weight, photocuring reaction may not proceed, and reduction rate of layer thickness, heat resistance,

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chemical resistance or the like tend to deteriorate. Also, if the adding amount exceeds 18 % by weight, solubility to base resin is saturated and crystal of the initiator deposits at the time of spin coating or coating layer leveling so that homogeneity of layer surface cannot be maintained and a defect such as layer roughness may be caused.

In preparing the photocurable resin composition, the photopolymerization initiator may be added from the beginning to the photocurable resin composition containing the fumarate copolymer. In the case of storing relatively for a long time, the initiator is preferably dispersed or solved in the photocurable resin composition right before the use.

If expecting improvement in light sensitivity, the sensitization agent may be added. As the sensitization agent to be used, a styryl based compound or coumarin based compound is preferable. Specifically, there may be 2-(p-dimethylaminostyryl)quinoline, 2-(p-diethylaminostyryl)quinoline, 4-(p-dimethylaminostyryl)quinoline, 4-(p-diethylaminostyryl)quinoline, 2-(p-dimethylaminostyryl)-3,3-3H-indole, 2-(p-diethylaminostyryl)-3,3-3H-indole, 2-(p-dimethylaminostyryl)benzoxazole, 2-(p-diethylaminostyryl)-benzoxazole, 2-(p-dimethylaminostyryl)benzimidazole, 2-(p-diethylaminostyryl)-benzimidazole or the like.

As the coumarin based compound, there may be 7-diethylamino-4-methylcoumarin, 7-ethylamino-4-trifluoromethylcoumarin, 4,6-diethylamino-7-ethylaminocoumarin, 3-(2-benzimidazolyl)-7-N,N-diethylaminocoumarin, 7-diethylamino

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cyclopenta(c)coumarin, 7-amino-4-trifluoromethylcoumarin, 1,2, 3,4,5,3H,6H,10H-tetrahydro-8-trifluoromethyl(1)benzopyrano-(9,9a,1-gh)-quinolizin-10-one, 7-ethylamino-6-methyl-4-trifluoromethylcoumarin, 1,2,3,4,5,3H,6H,10H-tetrahydro-
5 9-carbetoxy (1)benzopyrano-(9,9a,1-gh)-quinolizin-10-one or the like.

To the above-mentioned photocurable resin composition, if required, various additives such as a surfactant, a silane coupling agent or the like may be compounded besides the
10 above-mentioned component.

Further, in the case of forming a coloring layer of a color filter using the above-mentioned photocurable resin composition, a colorant such as a pigment, a dye or the like is compounded in the curable resin composition. As the colorant, according
15 to required color such as R, G, B or the like of a pixel part, an organic coloring agent or an inorganic coloring agent which has sufficient heat resistance to bear heating process of the color filter and has particle size which can disperse well can be used.

20 As the organic coloring agent, for example, a dye, an organic pigment, a natural color or the like may be used. Also, as the inorganic coloring agent, for example, an inorganic pigment, an extender or the like may be used.

As examples of the organic pigment, there may be compounds
25 categorized as pigment in the Color Index (C.I.; published by The Society of Dyers and Colourists), that is, pigments with the following Color Index (C.I.) number: yellow pigments such as C.I.

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pigment yellow 1, C.I. pigment yellow 3, C.I. pigment yellow 12, C.I. pigment yellow 13, C.I. pigment yellow 138, C.I. pigment yellow 150, C.I. pigment yellow 180, C.I. pigment yellow 185 or the like; red pigments such as C.I. pigment red 1, C.I. pigment red 2, C.I. pigment red 3, C.I. pigment red 254, C.I. pigment red 177 or the like; blue pigments such as C.I. pigment blue 15, C.I. pigment blue 15:3, C.I. pigment blue 15:4, C.I. pigment blue 15:6 or the like; C.I. pigment violet 23:19; and C.I. pigment green 36.

10 As examples of the inorganic pigment or the extender, there may be titanium oxide, barium sulfate, calcium oxide, zinc oxide, lead sulfate, yellow lead, zinc yellow, red oxide (III), cadmium red, ultramarine blue, Prussian blue, chromium oxide green, cobalt green, umber, titan black, synthetic iron black, carbon black
15 or the like. The colorant of the present invention may be used solely of in mixture of two or more.

The colorant is compounded in the photocurable resin composition generally by 40 to 75 % by weight, preferably 45 to 70 % by weight. If a compounding proportion of the colorant lowers
20 40 % by weight, inconvenience may be caused that tinting strength of each pixel part becomes insufficient, and a clear image display becomes difficult. On the other hand, if the compounding proportion exceeds 75 % by weight, inconvenience may be caused that the light transmittance of each pixel part becomes
25 insufficient or the like.

In the case of compounding the colorant to the photocurable resin composition, in order to evenly and stably disperse the

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colorant, a dispersant may be compounded in the photocurable resin composition. As the dispersant, for example, a cationic, anionic, nonionic, amphoteric, silicone based or fluorine based surfactant or the like may be used. Among the surfactants, a polymeric
5 surfactant (polymeric dispersant) exemplified below is preferable.

That is, a polymeric surfactant such as poly(oxyethylene) alkyl ethers such as poly(oxyethylene) lauryl ether, poly(oxyethylene) stearyl ether, poly(oxyethylene) oleyl ether
10 or the like; poly(oxyethylene) alkylphenyl ethers such as poly(oxyethylene) octylphenyl ether, poly(oxyethylene) nonylphenyl ether or the like; poly(ethylene glycol) diesters such as poly(ethylene glycol) dilaurate, poly(ethylene glycol) distearate or the like; sorbitan fatty acid esters; fatty acid
15 modified polyesters; tertiary amine modified polyurethanes or the like may be preferably used.

In the photocurable resin composition of the present invention, taking preparation of the resin composition and coating property into consideration, generally, solvent which has good
20 solubility with respect to the fumarate copolymer, the photocurable compound, the photopolymerization initiator or the like may be contained. As the solvent which can be used, for example, there may be an organic solvent such as an alcohol based solvent such as methyl alcohol, ethyl alcohol, N-propyl alcohol,
25 1-propyl alcohol or the like; a Cellosolve based solvent such as methoxy ethanol, ethoxy ethanol or the like; a Carbitol based solvent such as methoxyethoxy ethanol, ethoxyethoxy ethanol or

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the like; an ester based solvent such as ethyl acetate, butyl acetate, methylmethoxypropionate, ethylethoxypropionate, ethyl lactate or the like; a ketone based solvent such as acetone, methylisobutylketone, cyclohexanone or the like; a Cellosolve acetate based solvent such as methoxyethyl acetate, ethoxyethyl acetate, Ethyl Cellosolve acetate or the like; a Carbitol acetate based solvent such as methoxyethoxyethyl acetate, ethoxyethoxyethyl acetate or the like; an ether based solvent such as diethyl ether, ethylene glycol dimethyl ether, diethylene glycol dimethyl ether, tetrahydrofuran or the like; an aprotic amide solvent such as N,N-dimethylformamide, N,N-dimethylacetamide, N-methylpyrrolidone or the like; a lactone based solvent such as γ -butyrolactone or the like; an unsaturated hydrocarbon based solvent such as benzene, toluene, xylene, naphthalene or the like; a saturated hydrocarbon based solvent such as N-heptane, N-hexane, N-octane or the like. Among the solvents, the Cellosolve acetate based solvent such as methoxyethyl acetate, ethoxyethyl acetate, Ethyl Cellosolve acetate or the like; the Carbitol acetate based solvent such as methoxyethoxyethyl acetate, ethoxyethoxyethyl acetate or the like; the ether based solvent such as ethylene glycol dimethyl ether, diethylene glycol dimethyl ether, propylene glycol diethyl ether or the like; the ester based solvent such as methyl methoxy propionate, ethyl ethoxy propionate, ethyl lactate or the like may be particularly suitably used. More preferably, MBA (3-methoxybutyl acetate, $\text{CH}_3\text{CH}(\text{OCH}_3)\text{CH}_2\text{CH}_2\text{OCOCH}_3$), PGMEA (propylene glycol monomethyl ether acetate, $\text{CH}_3\text{OCH}_2\text{CH}(\text{CH}_3)\text{OCOCH}_3$),

DMDG (diethylene glycol dimethyl ether, $H_3COC_2H_4OCH_3$) or the mixture thereof may be used. Using these organic solvents, a solid content concentration is adjusted to be 5 to 50 % by weight.

In order to produce the above-mentioned photocurable resin composition, the above-mentioned fumarate copolymer, the photocurable compound, the photopolymerization initiator and other components may be poured in an appropriate solvent, and solved or dispersed by a general method such as a paint shaker, a beads mill, a sandgrind mill, a ball mill, an attritor mill, a two-roll mill, a three-roll mill or the like. As the fumarate copolymer which is a main polymer, a fumarate copolymer being active ingredient having refined to isolate after synthesis may be used or reaction solution obtained by the synthesis, the dried product thereof or the like may be used as it is.

When thus obtained photocurable resin composition is applied on a support to form a coating layer, and the coating layer is radiated with active energy beam such as ultraviolet ray, ionizing radiation or the like, the photocurable compound forms crosslinking bond to include the fumarate copolymer or the fumarate copolymer itself forms crosslinking bond if the fumarate copolymer contains an ethylenically unsaturated bond, and be cured.

A cured layer is excellent in thermal discoloration resistance, and hard to cause discoloration such as yellowing or the like or deteriorate transparency. Further, if the fumarate copolymer having an ethylenically unsaturated bond and the photocurable compound are used in combination, crosslinking bond

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is formed between the fumarate copolymer and the photocurable compound, the reaction point density of crosslinking becomes high, and the exposure sensitivity and the layer strength and hardness improve.

5 In the present invention, heat resistance (yellowing resistance) of a layer can be evaluated in the following manner. Firstly, a curable resin composition is applied on a substrate, dried if required, to form a coating layer. Herein, as the substrate, a substrate such as a transparent glass substrate,
10 which has no problem in a series of pattern forming process such as exposure, development or the like, can be used. There is no particular limit in a coating layer thickness. Generally, the thickness is about 1 to 10 μm . The coating layer is prebaked under an appropriate condition, for example, at 70 to 150 $^{\circ}\text{C}$ for
15 1 to 10 minutes. After prebaking, the coating layer is exposed to be cured at the radiation intensity which can completely cure the coating layer, and postbaked under an appropriate condition, for example, at 180 to 280 $^{\circ}\text{C}$ for 20 to 80 minutes.

The light transmittance (380 nm) of the thus obtained cured
20 layer is measured using the glass substrate as a reference. The transmittance measured at this point is referred as "transmittance before heating test".

Next, the cured layer on the glass substrate is heated at 250 $^{\circ}\text{C}$ for 1 hour to obtain a heat-tested cured layer. The
25 light transmittance (380 nm) of the thus obtained heat-tested cured layer on the glass substrate is measured using the glass substrate as a reference. The transmittance measured at this

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point is referred as "transmittance after heating test".

In this way, the light transmittance before and after the heating test is calculated, and the heat resistance of the cured layer can be evaluated from the ratio of the transmittance after heating test with respect to the transmittance before heating test. According to the present invention, the ratio of the light transmittance before and after heating test can be maintained by 90 % or more.

Further, in the present invention, the exposure sensitivity of a curable resin composition can be evaluated in the following manner. Firstly, a curable resin composition is applied on a substrate, dried if required, to form a coating layer. Herein, as the substrate, a substrate such as a transparent glass substrate, which has no problem in a series of pattern forming process such as exposure, development or the like, can be used. There is no particular limit in a coating layer thickness. Generally, the thickness is about 1 to 10 μm . The coating layer is prebaked under an appropriate condition, for example, at 70 to 150 $^{\circ}\text{C}$. for 1 to 10 minutes. After prebaking, the coating layer is exposed at a given radiation intensity and the layer thickness is measured. The layer thickness measured at this point is referred as "layer thickness before development".

Next, the prebaked coating layer is contacted to an appropriate developing agent to solve and remove an unexposed portion, the left exposed portion is washed if required, and the coating layer is developed. Herein, composition of the developing agent and the development condition may be

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appropriately selected according to a curable resin composition for the test. Needless to say, as the developing agent, a developing agent which hardly solves an exposed portion (a cured portion) of a curable resin composition and can completely solve unexposed portion is preferable. The developed coating layer is postbaked under an appropriate condition, for example, at 180 to 280 °C for 20 to 80 minutes. After postbaking, the coating layer thickness is measured, and it is referred as "final layer thickness after curing".

- 10 Using the thus measured layer thickness before development and final layer thickness after curing, a reduction rate of layer thickness can be calculated by the following formula:

15 Reduction rate of layer thickness (%) = (final layer thickness after curing (μm) / layer thickness before development (μm)) × 100

- 20 On the other hand, a similar curable resin composition is applied, dried and prebaked on a substrate similarly as above to form a coating layer for reference. The coating layer for reference is exposed at the radiation intensity which can completely cure the coating layer, and the layer thickness is measured. The layer thickness measured at this point is referred as "completely exposed layer thickness". Next, after postbaking the completely exposed coating layer in a similar manner as the sample without being developed, the layer thickness of the obtained layer is measured as in the same manner, and it is referred

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as "final layer thickness without development process". A reference reduction rate of layer thickness is calculated using the measured completely exposed layer thickness and final layer thickness without development process by the following formula:

5

Reference reduction rate of layer thickness (%) = (final layer thickness without development process (μm) / completely exposed layer thickness (μm)) $\times 100$

10

In this way, the reduction rate of layer thickness and the reference reduction rate of layer thickness are calculated, and the smallest exposure amount wherein the reduction rate of layer thickness is equal to the reference reduction rate of layer thickness with an accuracy of 1% is determined as a minimum exposure of the curable resin composition. When the minimum exposure is small, it can be evaluated to have high sensitivity.

15

According to the present invention, it is possible to obtain a curable resin composition having 100 mJ/cm² or less of thus determined minimum exposure.

20

A photocurable resin composition of the present invention is suitable for forming details of a color filter, for example, a coloring layer such as a pixel part, a black matrix layer or the like, a protective layer laid on the coloring layer and a columnar spacer to maintain a cell gap of a liquid crystal panel.

25

Also, a photocurable resin composition of the present invention can be utilized for display devices of other type besides a liquid crystal display device, for example, it may be suitably used for

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forming a protective layer, a pixel part, and other details of a color filter of an organic EL display device.

When a photocurable resin composition of the present invention is used as a protective layer or a pixel part of a color filter, yellowing hardly occurs by heating process during assembling a liquid crystal panel, and it has significantly excellent transparency. Further, when a fumarate copolymer having an ethylenically unsaturated bond and a curable compound as the third component are compounded in combination in the photocurable resin composition, the reaction point density of crosslinking reaction in the composition becomes high, and various physical properties such as the coating layer strength, the heat resistance, the chemical resistance or the like after curing are excellent.

A color filter is comprised of a black matrix formed on a transparent substrate in a predetermined pattern, a pixel part formed in a predetermined pattern on the black matrix, and a protective layer formed to cover the pixel part. If required, a transparent electrode for driving a liquid crystal may be formed on the protective layer. Also, a columnar spacer may be formed on the transparent electrode plate, the pixel part or the protective layer corresponding to a region wherein the black matrix layer is formed.

In the pixel part, a red pattern, a green pattern and a blue pattern are arranged in a desired form such as a mosaic type, a stripe type, a triangle type, a four-pixel aligned type or the like. The black matrix layer is provided between each pixel

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pattern and in predetermined region outside a region wherein a pixel part is formed. The coloring layer such as the pixel part, the black matrix layer or the like may be formed by various methods, for example, it can be formed in any of a dyeing method, a pigment
5 dispersing method, a printing method and an electrodeposition method. The black matrix layer may be formed by chromium deposition or the like. However, the coloring layer is preferably formed by the pigment dispersing method using the above-mentioned photocurable resin composition. That is, a colored or black
10 pigment is dispersed to the above-mentioned photocurable resin composition to prepare a coating composition, the coating composition is applied on one surface of the transparent substrate, and radiated with active energy beam such as ultraviolet ray, ionizing radiation or the like via a photomask to expose. After
15 alkaline development, the coating composition is heated to be cured in a clean oven or the like, thus, a coloring layer is formed. The coloring layer is generally formed in thickness of about 1.5 μm .

The protective layer may be formed by applying the
20 above-mentioned photocurable resin composition by a method such as a spin coater, roll coater, spraying, printing or the like. The protective layer is, for example, formed in thickness of about 2 μm . In the case of using the spin coater, spinning rate is set in the range of 500 to 1500 rpm. The coating layer of the
25 photocurable resin composition is radiated with active energy beam via a photomask and exposed. After alkaline development, the coating layer is heated and cured in a clean oven or the like,

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thus, a protective layer is obtained.

The transparent electrode of the protective layer is formed by a general method such as a sputtering method, a vacuum deposition method, a CVD method or the like using indium tin oxide (ITO), zinc oxide (ZnO), tin oxide (SnO) or the like, and alloy or the like thereof, and if required, formed in a predetermined pattern with the use of etching using a photoresist or a jig. The thickness of the transparent electrode is generally about 20 to 500 nm, preferably 100 to 300 nm.

20 The columnar spacer on the transparent electrode can be formed by applying the above-mentioned photocurable resin composition by a method such as a spin coater, roll coater, spraying, printing or the like, irradiating active energy beam via a photomask to expose, performing alkaline development, and heating to cure in a clean oven or the like. The columnar spacer, for example, is formed in height of about 5 μm . Spinning rate of a spin coater may be set in the range of 500 to 1500 rpm. similarly as forming the protective layer.

20 An orientation layer is formed in the inner surface side of the thus produced color filter, the color filter is disposed with an electrode substrate to face each other, and liquid crystal is filled in a gap and sealed, thereby, a liquid crystal panel can be obtained.

25 EXAMPLE

Example 1

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(Synthesis of a copolymer solution 1)

The following amount of monomers and 14 g of parbutyl O (product name, organic peroxide manufactured by NOF Corporation) were solved in 300 g of diethylene glycol dimethyl ether (DMDG).

- 5 The solution was dropped in a polymerization vessel containing 1000 g of DMDG adjusted to a temperature of 80 °C under nitrogen atmosphere for 6 hours, thereafter, the solution was subject to maturing at the same temperature for 4 hours to polymerize, thus, a copolymer solution 1 was obtained.

10

<Copolymerization composition>

- Dicyclohexyl fumarate (DCHF): 529 g
- Acrylic acid (AA): 171 g

15 (Preparation of a photocurable resin composition 1)

The following material of the following amount was agitated and mixed at room temperature, thus, a photocurable resin composition 1 was obtained.

20 <Composition of a photocurable resin composition 1>

- The above-mentioned copolymer solution 1 (solid content 35 %): 69.0 parts by weight
- Dipentaerythritol pentaacrylate (SR399, manufactured by Sartomer Company, Inc.): 11.0 parts by weight
- 25 ·Orthocresol novolac type epoxy resin (product name: Epikote 180S70; manufactured by Japan Epoxy Resins Co., Ltd.): 15.0 parts by weight

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·2-Methyl-1-(4-methylthiophenyl)-2-morpholinopropanone-1: 1.5

parts by weight

·2,2'-bis(0-chlorophenyl)-4,5,4',5'-tetraphenyl-1,2'-

biimidazole: 1.0 parts by weight

5 ·DMDG: 66.0 parts by weight

Example 2

(Synthesis of a raw material polymer)

10 The following amount of monomer and 12 g of perbutyl O
(product name, organic peroxide manufactured by NOF Corporation)
were solved in 258 g of diethylene glycol dimethyl ether (DMDG).
The solution was dropped in a polymerization vessel containing
859 g of DMDG adjusted to a temperature of 80 °C under nitrogen
15 atmosphere for 6 hours, thereafter, the solution was subject to
maturing at the same temperature for 4 hours to polymerize, thus,
a raw material polymer solution, a precursor of a copolymer
solution 2, was obtained.

20 <Copolymerization composition >

·Dicyclohexyl fumarate (DCHF): 469 g

·Acrylic acid (AA): 132 g

(Synthesis of a copolymer solution 2)

25 99 g of glycidyl methacrylate (GMA), 5 g of pyridine and
0.5 g of hydroquinone were fed to 1730 g of the obtained raw material
polymer solution in the above synthesis and solved uniformly.

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Next, air was bubbled in the reaction solution under agitation to raise temperature up to 80 °C, the reaction solution was reacted at 80 °C for 5 hours, thus, a copolymer solution 2 was obtained.

5 (Preparation of a photocurable resin composition 2)

Except that the resin used was changed to the copolymer solution 2, a composition was prepared similarly as Example 1, thus, a photocurable resin composition 2 was obtained.

10 Example 3

(Synthesis of a raw material polymer)

The following amount of monomers and 13.4 g of perbutyl O (product name, organic peroxide manufactured by NOF Corporation) were solved in 287 g of diethylene glycol dimethyl ether (DMDG). The solution was dropped in a polymerization vessel containing 957 g of DMDG adjusted to a temperature of 80 °C under nitrogen atmosphere for 6 hours, thereafter, the solution was subject to maturing at the same temperature for 4 hours to polymerize, thus, a raw material polymer solution, a precursor of a copolymer solution 3, was obtained.

<Copolymerization composition>

- Dicyclohexyl fumarate (DCHF): 557 g
- 25 • Acrylic acid (AA): 113 g

(Synthesis of a copolymer solution 3)

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30 g of glycidyl methacrylate (GMA), 1.5 g of pyridine and 0.15 g of hydroquinone were fed to 1914 g of the obtained raw material polymer solution in the above synthesis and solved uniformly. Next, air was bubbled in the reaction solution under agitation to raise temperature up to 80 °C, the reaction solution was reacted at 80 °C for 5 hours, thus, a copolymer solution 3 was obtained.

(Preparation of a photocurable resin composition 3)

10 Except that the resin used was changed to the copolymer solution 3, a composition was prepared similarly as Example 1, thus, a photocurable resin composition 3 was obtained.

Comparative example 1

15

(Synthesis of a copolymer solution 4)

The following amount of monomer and 3 g of azobisisobutyronitrile (AIBN) were solved together in 650 g of diethylene glycol dimethyl ether (DMDG). The solution was 20 dropped in a polymerization vessel containing 1000 g of DMDG at 100 °C for 6 hours to polymerize, thus, a copolymer solution 4 was obtained.

<Copolymerization composition>

25 ·Methyl methacrylate (MMA): 357 g
·Methacrylic acid (MAA): 181 g

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(Preparation of a photocurable resin composition 4)

Except that the resin used was changed to the copolymer solution 4, a composition was prepared similarly as Example 1, thus, a photocurable resin composition 4 was obtained.

- 5 The physical properties of the obtained copolymers are shown in Table 1.

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Table 1

	Copolymer composition (% by weight)				Acid value mgKOH/g	N _w x10 ⁴	C=C content mmol/g	Concen- tration %
	MMA	DCHF	MAA	AA	GMA			
Example 1	-	75.6	-	24.4	-	2.2	0	35
Example 2	-	67.0	-	18.8	14.2	2.4	1.0	35
Example 3	-	79.5	-	16.2	4.3	2.5	0.3	35
Comparative example 1	71.8	-	28.2	-	-	3.1	0	35

MMA: methyl methacrylate

DCHF: dicyclohexyl fumarate

MAA: methacrylic acid

AA: acrylic acid

GMA: glycidyl methacrylate

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Example 4

(1) Forming a black matrix

Firstly, components of the following amount were mixed,
5 and sufficiently dispersed by a sand mill, thus, a black pigment dispersion was prepared.

<Composition of a black pigment dispersion>

- Black pigment: 23 parts by weight
- 10 •Polymeric dispersant (product name: Disperbyk 111; manufactured by BYK-Chemie Japan KK): 2 parts by weight
- A solvent (DMDG): 75 parts by weight

Next, components of the following amount were sufficiently
15 mixed, thus, a resin composition for a photocurable black matrix was obtained.

<Composition of a resin composition for a photocurable black matrix>

- 20 •The above-mentioned black pigment dispersion: 61 parts by weight
- The photocurable resin composition 1 of Example 1: 20 parts by weight
- A solvent (DMDG): 30 parts by weight

25 After that, the above-mentioned resin composition for a photocurable black matrix was applied by a spin coater on a glass substrate (AL material, manufactured by Asahi Glass Co., Ltd.)

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having a thickness of 1.1 μm , and dried at 100 $^{\circ}\text{C}$ for 3 minutes, thus, a photocurable black matrix layer having a layer thickness of about 1 μm was formed. After the photocurable black matrix layer was exposed by a super high pressure mercury lamp in a shield pattern, the photocurable black matrix layer was developed by a 0.05 % potassium hydroxide aqueous solution. Then, heat treatment was performed by leaving the substrate under atmosphere of 180 $^{\circ}\text{C}$ for 30 minutes, thus, a black matrix was formed in a region wherein a shield portion was to be formed.

10

(2) Forming a coloring layer

A red (for R) photocurable resin ink of the following composition was applied (applied thickness of 1.5 μm) on a substrate wherein the black matrix was formed as above by a spin coating method, after that, the substrate was dried in an oven at 70 $^{\circ}\text{C}$ for 30 minutes.

Next, a photomask was disposed with a distance of 100 μm from a coating layer of the red (for R) photocurable resin ink, and only a region corresponding to a region wherein a coloring layer is formed was radiated with ultraviolet ray by a proximity aligner using a 2.0 kW super high pressure mercury lamp for 10 seconds. Next, the coating layer was dipped in a 0.05 wt% potassium hydroxide aqueous solution (solution temperature of 23 $^{\circ}\text{C}$) for 1 minute to perform alkaline development, and only an uncured portion of the coating layer of the red (for R) photocurable resin ink was removed. After that, heat treatment was performed by leaving the substrate under atmosphere of 180 $^{\circ}\text{C}$

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for 30 minutes, thus, a red relief pattern was formed in a region wherein a red pixel was to be formed.

Next, using a green (for G) photocurable resin ink of the following composition, with the similar process as forming the red relief pattern, a green relief pattern was formed in a region wherein a green pixel was to be formed.

Further, using a blue (for B) photocurable resin ink of the following composition, with the similar process as forming the red relief pattern, a blue relief pattern was formed in a region wherein a blue pixel was to be formed. Thus, a coloring layer comprising three colors comprising red (R), green (G) and blue (B) was formed.

<Composition of a red (for R) photocurable resin ink>

- C.I. pigment red 177: 10 parts by weight
- A polysulfonic acid type polymeric dispersant: 3 parts by weight
- The photocurable resin composition 1 of Example 1: 5 parts by weight
- 3-Methoxybutyl acetate: 82 parts by weight

<Composition of a green (for G) photocurable resin ink>

- C.I. pigment green 36: 10 parts by weight
- A polysulfonic acid type polymeric dispersant: 3 parts by weight
- The photocurable resin composition 1 of Example 1: 5 parts by weight
- 3-Methoxybutyl acetate: 82 parts by weight

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<Composition of a blue (for B) photocurable resin ink>

- C.I. pigment blue 15:6: 10 parts by weight
- A polysulfonic acid type polymeric dispersant: 3 parts by weight
- The photocurable resin composition 1 of Example 1: 5 parts by weight
- 3-Methoxybutyl acetate: 82 parts by weight

Example 5: Forming a protective layer

- 10 The photocurable resin composition 1 of Example 1 was applied on the substrate wherein the coloring layer was formed in Example 4 by a spin coating method, the substrate was dried, and a coating layer having a layer thickness of 2 μm when dried was formed.
- 15 A photomask was disposed with a distance of 100 μm from the coating layer of the photocurable resin composition 1, and only a region corresponding to a region wherein a coloring layer is formed was radiated with ultraviolet ray by a proximity aligner using a 2.0 kW super high pressure mercury lamp for 10 seconds.
- 20 Next, the substrate was dipped in a 0.05 wt% potassium hydroxide aqueous solution (solution temperature of 23 $^{\circ}\text{C}$) for 1 minute to perform alkaline development, and only an uncured portion of the coating layer of the photocurable resin composition was removed. After that, heat treatment was performed by leaving
- 25 the substrate under atmosphere of 200 $^{\circ}\text{C}$ for 30 minutes to form a protective layer, thus, a color filter of the present invention was obtained.

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Example 6: Forming a spacer

The photocurable resin composition 1 of Example 1 was applied on the substrate wherein the coloring layer was formed in Example 4 by a spin coating method, the substrate was dried, and a coating layer having a layer thickness of 5 μm when dried was formed.

A photomask was disposed with a distance of 100 μm from the coating layer of the photocurable resin composition 1, and only a region of a black matrix wherein a spacer is formed was radiated with ultraviolet ray by a proximity aligner using a 2.0 kW super high pressure mercury lamp for 10 seconds. Next, the coating layer was dipped in a 0.05 wt% potassium hydroxide aqueous solution (solution temperature of 23 $^{\circ}\text{C}$) for 1 minute to perform alkaline development, and only an uncured portion of the coating layer of the photocurable resin composition was removed. After that, heat treatment was performed by leaving the substrate under atmosphere of 200 $^{\circ}\text{C}$ for 30 minutes to form a fixed spacer, thus, a color filter of the present invention was obtained.

On the surface of the obtained color filter including the fixed spacer, a DC magnetron sputtering method was performed at a substrate temperature of 200 $^{\circ}\text{C}$ using argon and oxygen as discharge gas with ITO as target to form a transparent electrode layer. Then, further on the transparent electrode layer, an orientation layer made of polyimide was formed.

Next, the above-mentioned color filter and the glass

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substrate wherein TFT was formed were coupled to form a cell by applying pressure of 0.3 kg/cm² at 150 °C using an epoxy resin as a sealing material, and TN liquid crystal was introduced and sealed, thus, a liquid crystal display device was formed.

5

Example 7

Respectively on the coloring layer of the glass substrate wherein the coloring layer was formed in Example 4, and on the protective layer of the color filter wherein the coloring layer and the protective layer were formed in Example 5, a DC magnetron sputtering method was performed at a substrate temperature of 200 °C using argon and oxygen as discharge gas with ITO as target to form a transparent electrode layer. Then, further on the transparent electrode layer, an orientation layer made of polyimide was formed, thus, a color filter was obtained.

(Evaluation of heat resistance)

On a glass substrate of 10 cm square, the photocurable resin composition 1 obtained in Example 1 was applied by a spin coater (Model 1H-DX2, manufactured by MIKASA) and dried to form a coating layer of a layer thickness of 2.2 μm when dried. The coating layer was heated on a hot plate at 90 °C for 3 minutes. After heating, the coating layer was radiated with ultraviolet ray having intensity of 100 mJ/cm² (405 nm illuminance equivalent) by a UV aligner (Model MA 1200, manufactured by DAINIPPON SCREEN MFG. CO., LTD.) equipped with a 2.0 kW super high pressure mercury

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lamp.

After ultraviolet ray radiation, the coating layer was dried in a clean oven (SCOV-250 Hy-So, manufactured by Oshitari Laboratory, Inc.) at 200 °C for 30 minutes, thus, a cured layer
5 having a layer thickness of 2.0 μm was obtained. The light transmittance (380 nm) of the thus obtained cured layer on the glass substrate was measured using the glass substrate as a reference by a spectrophotometer (UV-3100PC, manufactured by Shimadzu Corporation).

10 Next, the glass substrate with the cured layer was heated in a clean oven (SCOV-250 Hy-So, manufactured by Oshitari Laboratory, Inc.) at 250°C for 1 hour, thus, a heat-tested cured layer was obtained. The visible light transmittance (380 to 780
15 nm) of the thus obtained heat-tested cured layer on the glass substrate was measured using the glass substrate as a reference by a spectrophotometer (UV-3100PC, Shimadzu Corporation).

The heat resistance of the cured layer was evaluated from a change in light transmittance (380 nm) before and after the above-mentioned heating test. Further, in the same manner as
20 the above, a coating layers of the photocurable resin composition 2 obtained in Example 2, the photocurable resin composition 3 obtained in Example 3 and the photocurable resin composition 4 obtained in Comparative example 1 were formed. The heat resistance of the cured layers was evaluated from a change in
25 light transmittance before and after the heating test.

The results of heat resistance of thus formed cured layers of the photocurable resin compositions 1 to 4 are shown in Table

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2.

Table 2

	Example 1	Example 2	Comparative example 3	Comparative example 1
Transmittance at 380 nm after heating (%)	92	90	91	75

5

(Evaluation of sensitivity)

On a glass substrate of 10 cm pixel, the photocurable resin composition 1 obtained in Example 1 was applied by a spin coater (Model 1H-DX2, manufactured by MIKASA) and dried to form a coating layer of a layer thickness of 2 μm when dried. The coating layer was heated on a hot plate at 90 $^{\circ}\text{C}$ for 3 minutes. After heating, each region of the coating layer divided into quarters was radiated with ultraviolet ray having intensity of 50, 100, 150 and 200 mJ/cm^2 (405 nm illuminance equivalent) by a UV aligner (Model MA1200, manufactured by DAINIPPON SCREEN MFG. CO., LTD.) equipped with a 2.0 kW super high pressure mercury lamp.

After ultraviolet ray radiation, the coating layer of each of the four regions was scraped in a rectangular form having a size of about 1 mm x 3 mm to partly expose a glass substrate. A layer thickness of each radiated region was measured by a stylus surface roughness measuring device (Dektak 1600, manufactured by ANELVA Corporation), and it was referred as a layer thickness before development.

Next, on the exposed portion of the coating layer, a 0.05wt%

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potassium hydroxide aqueous solution was sprayed by a spin developing machine (INK, MODEL:915, manufactured by Applied Process Technology) for 60 seconds to solve and remove an unexposed portion, then, the left exposed portion was developed by washing with pure water for 60 seconds. After development, the layer of the exposed portion was heated in a clean oven (SCOV-250 Hy-So, manufactured by Oshitari Laboratory, Inc.) at 200°C for 30 minutes. Then, the layer thickness of each region of the obtained layer was measured in the same manner as the above, and it was referred as a final layer thickness after curing.

A reduction rate of layer thickness was calculated from the thus measured layer thickness before development and final layer thickness after curing by the following formula:

Reduction rate of layer thickness (%) = (final layer thickness after curing (μm) / layer thickness before development (μm)) × 100

On the other hand, a reference reduction rate of layer thickness was determined in the following manner. Firstly, except that all surfaces of the coating layer were exposed at an intensity of 100 mJ/cm², a completely exposed layer thickness of the photocurable resin composition 1 was measured as in the same manner as the samples. Next, after the coating layer exposed at 100 mJ/cm² was heated as in the manner as the samples without being developed, the layer thickness of the obtained layer was measured as in the same manner as above, and it was referred as

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a final layer thickness without development process. Then, a reference reduction rate of layer thickness was calculated from the measured completely exposed layer thickness and final layer thickness without development process by the following formula:

5

Reference reduction rate of layer thickness (%) = (final layer thickness without development process (μm) / completely exposed layer thickness (μm)) × 100

10

The smallest exposure amount wherein the thus calculated reduction rate of layer thickness is equal to the reference reduction rate of layer thickness with an accuracy of 1 % was determined as a minimum exposure of the photocurable resin composition 1.

15

Further, in the same manner as aforementioned, layers of the photocurable resin composition 2 obtained in Example 2, the photocurable resin composition 3 obtained in Example 3 and the photocurable resin composition 4 obtained in Comparative example 1 were formed, layer thickness before development, final layer thickness after curing, completely exposed layer thickness, and final layer thickness without development process were measured, and minimum exposure of each of the photocurable resin compositions 2 to 4 was determined.

20

In this way, minimum exposure of each photocurable resin composition 1 to 4 was determined. The results are shown in Table 3.

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Table 3

Example No.	Composition No.	Minimum curing exposure (mJ/cm^2)
Example 1	Curable resin composition 1	200
Example 2	Curable resin composition 2	100
Example 3	Curable resin composition 3	150
Comparative example 1	Curable resin composition 4	200

Industrial Applicability

5

As explained above, the fumarate copolymer used in the present invention as a binder is comprised by linkage of a constituent unit of the Formula 1 which contributes to thermal discoloration resistance and acidic functional group containing unit which contributes to acid or alkaline solubility, further
10 if required, an ethylenically unsaturated bond containing unit which contributes to reaction curability, an aromatic carbocycle containing unit which contributes to coatability, or an ester group containing unit which inhibits alkaline developing ability.

15

The fumarate copolymer is not only excellent in the thermal discoloration resistance but is also capable of accordingly adjusting reaction curability, alkaline solubility, coatability or the like by changing the containing ratio of each constituent unit. Hence, the copolymer can be suitably used as a binder component of a
20 reaction curable resin composition such as photo-curing, heat-curing or the like, and various minute structures,

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particularly, details of a color filter can be formed using the reaction curable resin composition.

A photocurable resin composition for forming a protective layer, RGB pixels, a black matrix or a spacer of a color filter
5 provided by the present invention contains the fumarate copolymer as a binder component.

The photocurable resin composition using the fumarate copolymer is suitable for forming details of a color filter, particularly, a coloring layer such as a pixel part, a black matrix
10 or the like, a protective layer laid on the coloring layer or a columnar spacer for maintaining a cell gap of a liquid crystal panel of a color filter.

The photocurable resin composition for forming a protective layer, RGB pixels, a black matrix or a spacer of a
15 color filter of the present invention hardly causes yellowing when used as a protective layer or a pixel part of a color filter and is excellent in transparency.

Particularly, when the fumarate copolymer is contained as a binder component, and if required, a multifunctional
20 polymerizable compound having two or more ethylenically unsaturated bonds is compounded in combination, a reaction point density of crosslinking reaction in the composition becomes high, and various physical properties such as coating layer strength, heat resistance, chemical resistance or the like after curing
25 are excellent.

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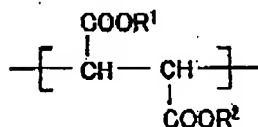
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CLAIMS

1. A photocurable resin composition for forming a protective layer, RGB pixels, a black matrix or a spacer of a color filter, wherein
- 5 as a binder component a copolymer comprising at least a molecular structure in which a constituent unit represented by the following Formula 1 and a constituent unit having an acidic functional group(s) are linked is contained:

10 Formula 1

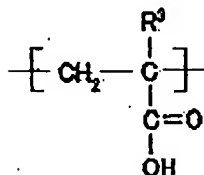


wherein, each of R^1 and R^2 is independently a branched C_{3-8} alkyl group which may be substituted, or a C_{4-8} cycloalkyl group which may be substituted.

15

2. A photocurable resin composition according to Claim 1, wherein the constituent unit having an acidic functional group(s) is a constituent unit represented by the following Formula 2:

20 Formula 2



wherein, R^3 is a hydrogen atom, methyl group or carboxymethyl

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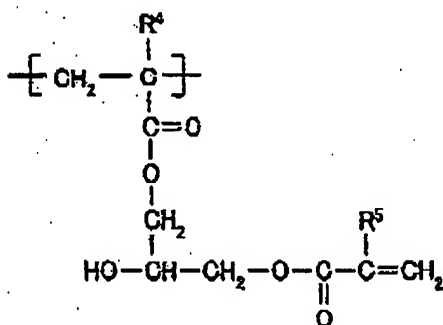
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group.

3. A photocurable resin composition according to Claim 1, wherein the copolymer is further comprised of a constituent unit with an ethylenically unsaturated bond.

4. A photocurable resin composition according to Claim 3, wherein the constituent unit with an ethylenically unsaturated bond is a constituent unit represented by the following Formula 3 or a constituent unit represented by the following Formula 4:

Formula 3

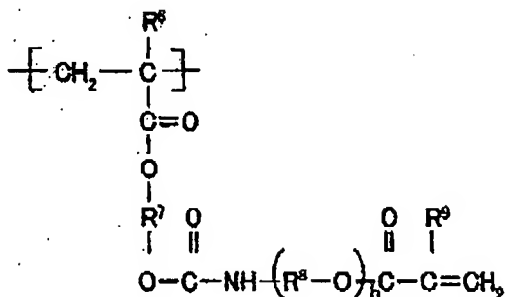


wherein, R⁴ and R⁵ are respectively a hydrogen atom or methyl group;

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Formula 4



wherein, R⁵ and R⁹ are independently a hydrogen atom or methyl group; R⁷ is a C₂₋₄ alkylene group; R⁸ is an alkylene group; "h" is 0 or 1.

5. A photocurable resin composition according to Claim 1, wherein an acid value of the copolymer is 40 to 200 mg KOH/g.
6. A photocurable resin composition according to Claim 3, wherein an acid value of the copolymer is 40 to 200 mg KOH/g and an ethylenically unsaturated bond content is 0.5 to 2.0 mmol/g.
7. A photocurable resin composition according to Claim 1, wherein a weight average molecular weight of the copolymer is 5,000 to 100,000.
8. A photocurable resin composition according to Claim 1, wherein the copolymer is contained 5 to 80 % by weight in ratio of the solid content.
9. A photocurable resin composition according to Claim 1, wherein

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a photocurable compound is further contained.

10. A photocurable resin composition according to Claim 1, wherein a photopolymerization initiator is further contained.

5

11. A photocurable resin composition according to Claim 1, wherein a compound having two or more epoxy groups in the molecular is further contained.

10 12. A photocurable resin composition according to Claim 1, wherein a colorant is further contained.

13. A photocurable resin composition according to Claim 1, wherein when a cured layer of the photocurable resin composition is heated at 250 °C for 1 hour, the light transmittance at wavelength of 380 nm of the cured layer after heating is 90% or more with respect to the light transmittance at the same wavelength of the cured layer before heating.

20 14. A photocurable resin composition according to Claim 1, wherein the photocurable resin composition is used for producing a color filter.

25 15. A color filter comprising a transparent substrate and a coloring layer formed on the transparent substrate, wherein the coloring layer is RGB pixels or a black matrix formed by curing the photocurable resin composition of Claim 1.

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16. A color filter comprising a transparent substrate, a coloring layer formed on the transparent substrate and a protective layer laid on the coloring layer, wherein the protective layer is formed
5 by curing the photocurable resin composition of Claim 1.

17. A color filter comprising a transparent substrate, a coloring layer formed on the transparent substrate, a spacer provided in a position superposed on a non-display portion to maintain a gap
10 between electrode substrates disposed to face each other, wherein the spacer is formed by curing the photocurable resin composition of Claim 1.

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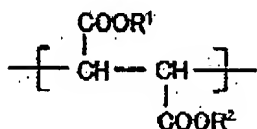
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ABSTRACT

A curable resin composition is provided which uses a fumarate copolymer which is excellent in thermal discoloration resistance as a binder component and is capable of forming details of a color filter. The curable resin composition of the present invention is a photocurable resin composition for forming a protective layer, RGB pixels, a black matrix or a spacer of a color filter, and contains as a binder component a fumarate copolymer having at least a molecular structure wherein a constituent unit represented by the following Formula 1 and a constituent unit having an acidic functional group(s) are linked, preferably further having a constituent unit with an ethylenically unsaturated bond:

15

Formula 1



wherein, each of R¹ and R² is independently a branched C₃₋₈ alkyl group which may be substituted, or a C₄₋₈ cycloalkyl group which may be substituted.

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FIG. 1

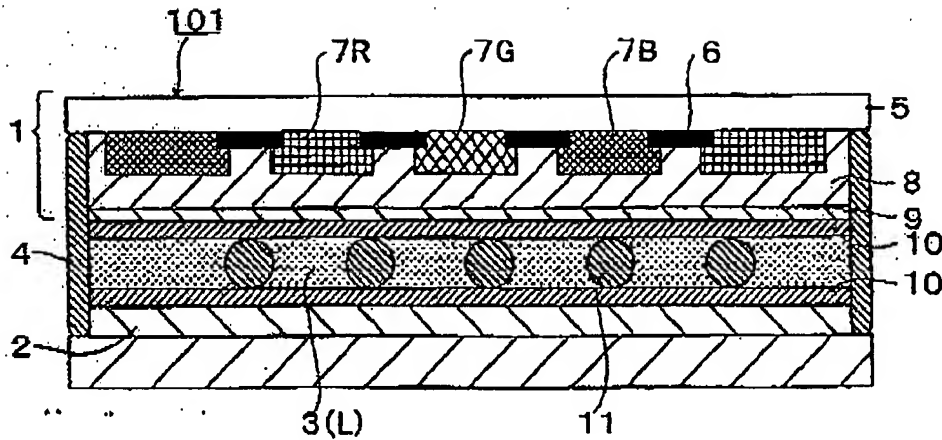
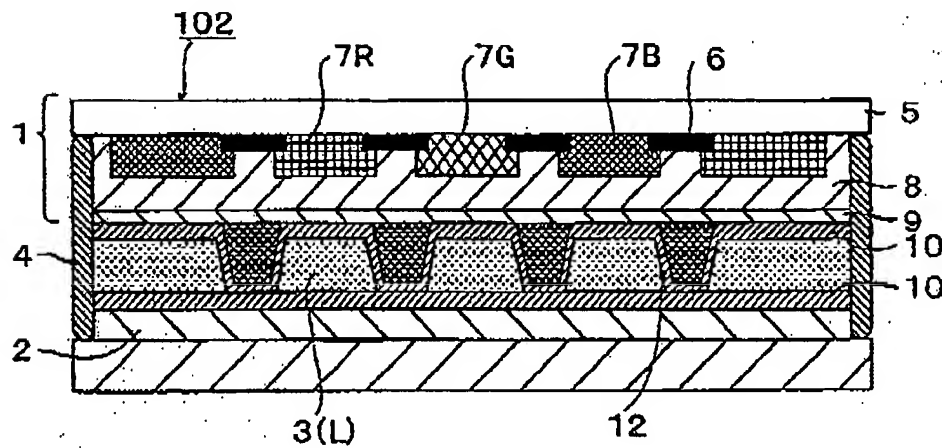


FIG. 2





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HL84425/000/DCO

2. Patent application number

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Second Floor Suite, Riverside Buildings
108 Walcot Street
Bath BA1 5BG
United Kingdom

Patents ADP number (if you know it)

If the applicant is a corporate body, give the country/state of its incorporation

GB

8047151002

4. Title of the invention

PROCESSOR NETWORK

5. Name of your agent (if you have one)

Haseltine Lake

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Date of filing
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Date of filing
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- b) there is an inventor who is not named as an applicant, or
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Description

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Claim(s)

3

Abstract

1

Drawing(s)

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Translations of priority documents

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1

Request for substantive examination (Patents Form 10/77)

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11.

I/We request the grant of a patent on the basis of this application.

Signature

Date

D C O'Connell

21 February 2003

12. Name and daytime telephone number of person to contact in the United Kingdom

Mr D C O'Connell

[0117] 910 3200

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PROCESSOR NETWORK

This invention relates to a processor network, and in particular to an array of processors having software tasks allocated thereto. In other aspects, the invention relates to a method and a software product for automatically allocating software tasks to processors in an array.

10 Processor systems can be categorised as follows:-

Single Instruction, Single Data (SISD). This is a conventional system containing a single processor that is controlled by an instruction stream.

15

Single Instruction, Multiple Data (SIMD), sometimes known as an array processor, because each instruction causes the same operation to be performed in parallel on multiple data elements. This type of processor is often used for matrix calculations and in supercomputers.

20

Multiple Instruction, Multiple Data (MIMD). This type of system can be thought of as multiple independent processors, each performing different instructions on the same data.

25

MIMD processors can be divided into a number of sub-classes, including:-

30

Superscalar, where a single program or instruction stream is split into groups of instructions that are not dependent on each other by the processor hardware at run time. These groups of instructions are processed at the same time in separate execution units. This type of processor only executes one instruction

35

stream at a time, and so is really just an enhanced SISD machine.

Very Long Instruction Word (VLIW). Like superscalar, a VLIW machine has multiple execution units executing a single instruction stream, but in this case the instructions are parallelised by a compiler and assembled into long words, with all instructions in the same word being executed in parallel. VLIW machines may contain anything from two to about twenty execution units, but the ability of compilers to make efficient use of these execution units falls off rapidly with anything more than two or three of them.

Multi-threaded. In essence these may be superscalar or VLIW, with different execution units executing different threads of program, which are independent of each other except for defined points of communication, where the threads are synchronized. Although the threads can be parts of separate programs, they all share common memory, which limits the number of execution units.

Shared memory. Here, a number of conventional processors communicate via a shared area of memory. This may either be genuine multi-port memory, or processors may arbitrate for use of the shared memory. Processors usually also have local memory. Each processor executes genuinely independent streams of instructions, and where they need to communicate information this is performed using various well-established protocols such as sockets. By its nature, inter-processor communication in shared memory architectures is relatively slow, although large amounts of data may be transferred on each communication event.

Networked processors. These communicate in much the same way as shared-memory processors, except that communication is via a network. Communication is even slower and is usually performed using standard communications protocols.

Most of these MIMD multi-processor architectures are characterised by relatively slow inter-processor communications and/or limited inter-processor communications bandwidth when there are more than a few processors. Superscalar, VLIW and multi-threaded architectures are limited because all the execution units share common memory, and usually common registers within the execution units; shared memory architectures are limited because, if all the processors in a system are able to communicate with each other, they must all share the limited bandwidth to the common area of memory.

For network processors, the speed and bandwidth of communication is determined by the type of network. If data can only be sent from a processor to one other processor at one time, then the overall bandwidth is limited, but there are many other topologies that include the use of switches, routers, point-to-point links between individual processors and switch fabrics.

Regardless of the type of multiprocessor system, if the processors form part of a single system, rather than just independently working on separate tasks and sharing some of the same resources, the various parts of the overall software task must be allocated to different processors. Methods of doing this include:-

Using one or more supervisory processors that allocate tasks to the other processors at run time. This can work well if the tasks to be allocated take a relatively long time to complete, but can be very difficult in real time systems that must perform a number of asynchronous tasks.

Manually allocating processes to processors. By its nature, this usually needs to be done at compile time. For many real time applications this is often preferred, as the programmer can ensure that there are always enough resources available for the real time tasks. However, with large numbers of processes and processors the task becomes difficult, especially when the software is modified and processes need to be reallocated.

Automatically allocating processes to processors at compile time. This has the same advantages as manual allocation for real time systems, with the additional advantage of greatly reduced design time and ease of maintenance for systems that include large numbers of processes and processors.

The present invention is concerned with allocation of processes to processors at compile time.

As processor clock speeds increase and architectures become more sophisticated, each processor can accomplish many more tasks in a given time period. This means that tasks can be performed on processors that required special-purpose hardware in the past. This has enabled new classes of problem to be addressed, but has created some new problems in real time processing.

Real time processing is defined as processing where results are required by a particular time, and is used in a huge range of applications from washing machines, through automotive engine controls and digital

5 entertainment systems, to base stations for mobile communications. In this latter application, a single

~~base station may perform complex signal processing and~~
control for hundreds of voice and data calls at one time, a task that may require hundreds of processors.

10 In such real time systems, the jobs of scheduling tasks to be run on the individual processors at specific times, and arbitrating for use of shared resources, have become increasingly difficult. The scheduling issue has arisen in part because individual processors
15 are capable of running tens or even hundreds of different processes, but, whereas some of these processes occur all the time at regular intervals, others are asynchronous and may only occur every few minutes or hours. If tasks are scheduled incorrectly,
20 then a comparatively rare sequence of events can lead to failure of the system. Moreover, because the events are rare, it is a practical impossibility to verify the correct operation of the system in all circumstances.

25 One solution to this problem is to use a larger number of smaller, simpler processors and allocate a small number of fixed tasks to each processor. Each individual processor is cheap, so it is possible for some to be dedicated to servicing fairly rare,
30 asynchronous tasks that need to be completed in a short period of time. However, the use of many small processors compounds the problem of arbitration, and in particular arbitration for shared bus or network resources. One way of overcoming this is to use a bus
35 structure and associated programming methodology that guarantees that the required bus resources are

available for each communication path. One such structure is described in WO02/50624.

In one aspect, the present invention relates to a
5 method of automatically allocating processes to
processors and assigning communications resources at
compile-time-using-information-provided-by-the-
programmer. In another aspect, the invention relates
to a processor array, having processes allocated to
10 processors.

More specifically, the invention relates to a method of
allocating processing tasks in multi-processor systems
in such a way that the resources required to
15 communicate data between the different processors are
guaranteed. The invention is described in relation to
a processor array of the general type described in
WO02/50624, but it is applicable to any multi-processor
system that allows the allocation of slots on the buses
20 that are used to communicate data between processors.

For a better understanding of the present invention,
reference will now be made by way of example to the
accompanying drawings, in which:-

25 Figure 1 is a block schematic diagram of a processor
array in accordance with the present invention.

Figure 2 is an enlarged block schematic diagram of a
30 part of the processor array of Figure 1.

Figure 3 is an enlarged block schematic diagram of
another part of the processor array of Figure 1.

35 Figure 4 is an enlarged block schematic diagram of a
further part of the processor array of Figure 1.

Figure 5 is an enlarged block schematic diagram of a further part of the processor array of Figure 1.

Figure 6 is an enlarged block schematic diagram of a
5 still further part of the processor array of Figure 1.

~~Figure 7 illustrates a process operating on the~~
processor array of Figure 1.

10 Figure 8 is a flow chart illustrating a method in accordance with the present invention.

Referring to Figure 1, a processor array of the general
15 type described in WO02/50624 consists of a plurality of processors 20, arranged in a matrix. Figure 1 shows six rows, each consisting of ten processors, with the processors in each row numbered P0, P1, P2, ..., P8, P9, giving a total of 60 processors in the array. This is
20 sufficient to illustrate the operation of the invention, although one preferred embodiment of the invention has over 400 processors. Each processor 20 is connected to a segment of a horizontal bus running from left to right, 32, and a segment of a horizontal
25 bus running from right to left, 36, by means of connectors, 50. These horizontal bus segments 32, 36 are connected to vertical bus segments 21, 23 running upwards and vertical bus segments 22, 24 running downwards at switches 55, as shown.

30

Although Figure 1 shows one form of processor array in which the present invention may be used, it should be noted that the invention is also applicable to other forms of processor array.

35

Each bus in Figure 1 consists of a plurality of data lines, typically 32 or 64, a data valid signal line and two acknowledge signal lines, namely an acknowledge signal and a resend acknowledge signal.

5

The structure of each of the switches 55 is illustrated with reference to Figure 2. The switch 55 includes a RAM 61, which is pre-loaded with data. The switch further includes a controller 60, which contains a
10 counter that counts through the addresses of the RAM 61 in a pre-determined sequence. This same sequence is repeated indefinitely, and the time taken to complete the sequence, measured in cycles of the system clock, is referred to as the sequence period. On each clock
15 cycle, the output data from RAM 61 is loaded into a register 62.

The switch 55 has six output buses, namely the respective left to right horizontal bus, the right to
20 left horizontal bus, the two upwards vertical bus segments, and the two downwards vertical bus segments, but the connections to only one of these output buses are shown in Figure 2 for clarity. Each of the six output buses consists of a bus segment 66 (which
25 consists of the 32 or 64 line data bus and the data valid signal line), plus lines 68 for output acknowledge and resend acknowledge signals.

A multiplexer 65 has seven inputs, namely from the
30 respective left to right horizontal bus, the right to left horizontal bus, the two upwards vertical bus segments, the two downwards vertical bus segments, and from a constant zero source. The multiplexer 65 has a control input 64 from the register 62. Depending on
35 the content of the register 62, the data on a selected one of these inputs during that cycle is passed to the

output line 66. The constant zero input is preferably selected when the output bus is not being used, so that power is not used to alter the value on the bus unnecessarily.

5

At the same time, the value from the register 62 is also supplied to a block 67, which receives acknowledge and resend acknowledge signals from the respective left to right horizontal bus, the right to left horizontal bus, the two upwards vertical bus segments, the two downwards vertical bus segments, and from a constant zero source, and selects a pair of output acknowledge signals on line 68.

10

Figure 3 is an enlarged block schematic diagram showing how two of the processors 20 are connected to segments of the left to right horizontal bus 32 and the right to left horizontal bus 36 at respective connectors 50. A segment of the bus, defined as the portion between two multiplexers 51, is connected to an input of a processor by a connection 25. An output of a processor is connected to a segment of the bus through an output bus segment 26 and another multiplexer 51. In addition, acknowledge signals from processors are combined with other acknowledge signals on the buses in acknowledge combining blocks 27.

25

The select inputs of multiplexers 51 and blocks 27 are under control of circuitry within the associated processor.

30

All communication within the array takes place in a predetermined sequence. In one embodiment, the sequence period is 1024 clock cycles. Each switch and each processor contains a counter that counts for the sequence period. On each cycle of this sequence, each

35

switch selects one of its input buses onto each of its six output buses. At predetermined cycles in the sequence, processors load data from their input bus segments via connection 25, and switch data onto their
5 output bus segments using the multiplexers, 51.

As a minimum, each processor must be capable of controlling its associated multiplexers and acknowledge combining blocks, loading data from the bus segments to
10 which it is connected at the correct times in sequence, and performing some useful function on the data, even if this only consists of storing the data.

The method by which data is communicated between
15 processors will be described by way of example with reference to Figure 4, which shows a part of the array in Figure 1, in which a processor in row "x" and column "y" is identified as Pxy.

20 For the purposes of illustration, a situation will be described in which data is to be sent from processor P24 to processor P15. At a predefined clock cycle, the sending processor P24 enables the data onto bus segment 80, switch SW21 switches this data onto bus segment 72,
25 switch SW11 switches it onto bus segment 76 and the receiving processor P15 loads the data.

Communications paths can be established between other processors in the array at the same time, provided that
30 they do not use any of the bus segments 80, 72 or 76. In this preferred embodiment of the invention, the sending processor P24 and the receiving processor P15 are programmed to perform one or a small number of specific tasks one or more times during a sequence
35 period. As a result, it may be necessary to establish a communications path between the sending processor P24

and the receiving processor P15 multiple times per sequence period.

More specifically, the preferred embodiment of the invention allows the communications path to be established once every 2, 4, 8, 16, or any power of two up to 1024, clock cycles.

At clock cycles when the communications path between the sending processor P24 and the receiving processor P15 is not established, the bus segments 80, 72 and 76 may be used as part of a communications path between any other pair of processors.

Each processor in the array can communicate with any other processor, although it is desirable for processes to be allocated to the processors in such a way that each processor communicates most frequently with its near neighbours, in order to reduce the number of bus segments used during each transfer.

In the preferred embodiment of the invention, each processor has the overall structure shown in Figure 5. The processor core 11 is connected to instruction memory 15 and data memory 16, and also to a configuration bus interface 10, which is used for configuration and monitoring, and to input/output ports 12, which are connected through bus connectors 50 to the respective buses, as described above.

The ports 12 are structured as shown in Figure 6. For clarity, this shows only the ports connected to the respective left to right bus 32, and not those connected to the respective right to left bus 36, and does not show control or timing details. Each communications channel for sending data between a

processor and one or more other processor is allocated a pair of buffers, namely an input pair 121, 122 for an input port or an output pair 123, 124 for an output port. The input ports are connected to the processor
 5 core 11 via a multiplexer 120, and the output ports are connected to the array bus 32 via a multiplexer 125 and a-multiplexer-51-

For one processor to send data to another, the sending
 10 processor core executes an instruction that transfers the data to an output port buffer, 124. If there is already data in the buffer 124 that is allocated to that communications channel, then the data is transferred to buffer 123, and if buffer 123 is also
 15 occupied then the processor core is stopped until a buffer becomes available. More buffers can be used for each communications channel, but it will be shown below that two is sufficient for the applications being considered. On the cycle allocated to the particular
 20 communications channel (the "slot"), data is multiplexed onto the array bus segment using multiplexers 125 and 51 and routed to the destination processor or processors as described above.

25 In a receiving processor, the data is loaded into a buffer 121 or 122 that has been allocated to that channel. The processor core 11 on the receiving processor can then execute instructions that transfer data from the ports via the multiplexer 120. When data
 30 is received, if both buffers 121 and 122 that are allocated to the communication channel are empty, then the data word will be put in buffer 121. If buffer 121 is already occupied, then the data word will be put in buffer 122. The following paragraphs illustrate what
 35 happens if both buffers 121 and 122 are occupied.

It will be apparent from the above description that, although slots for the transfer of data from processor to processor are allocated on a regular cyclical basis, the presence of the buffers in the output and input ports means that the processor core can transfer data to and from the ports at any time, provided it does not ~~cause the output buffers to overflow or the input buffers to underflow.~~ This is illustrated in the example in the table below, where the column headings have the following meanings:-

Cycle. For the purposes of this example, each system clock cycle has been numbered.

PUT. The transfer of data from the processor core to an output port is termed a "PUT". In the table, an entry appears in the PUT column whenever the sending processor core transfers data to the output port. The entry shows the data value that is transferred. As outlined above, the PUT is asynchronous to the transfer of data between processors; the timing is determined by the software running on the processor core.

OBuffer0. The contents of output buffer 0 in the sending processor (the output buffer 124 connected to the multiplexer 125 in Figure 6).

OBuffer1. The contents of output buffer 1 in the sending processor (the output buffer 123 connected to the processor core 11 in Figure 6).

Slot. Indicates cycles during which data is transferred. In this example, data is transferred every four cycles. The slots are numbered for clarity.

IBuffer0. The contents of input buffer 0 in the receiving processor (the input buffer 121 connected to the processor core 120 in Figure 6).

- 5 IBuffer1. The contents of input buffer 1 in the receiving processor (the input buffer 122 connected to the bus-32 in Figure 6).

10 GET. The transfer of data from an input port to the processor is termed a "GET". In the table, an entry appears in the GET column whenever the receiving processor transfers data from the input port. The entry shows the data value that is transferred. As outlined above, the GET is asynchronous to the transfer
15 of data between processors; the timing is determined by the software running on the processor core.

Cycle	PUT	OBuffer1	OBuffer0	Slot	IBuffer1	IBuffer0	GET
0							
1	D0		D0				
2			D0				
3			D0	1			
4						D0	
5	D1		D1			D0	
6	D2	D2	D1			D0	
7		D2	D1	2		D0	
8			D2		D1	D0	
9			D2			D1	D0
10			D2			D1	
11			D2	3	D2	D1	
12					D2	D1	
13						D2	D1
14						D2	
15				4		D2	
16						D2	

17							D2
18							

This invention preferably uses a method of writing software in manner that can be used to program the processors in a multi-processor system, such as the one described above. In particular, it provides a method of capturing a programmer's intentions concerning communications bandwidth requirements between processors and using this to assign bus resources to ensure deterministic communications. This will be explained by means of an example.

An example program is given below, and is represented diagrammatically in Figure 7. In the example, the software that runs on the processors is written in assembler so that the operations of PUT to and GET from the ports can clearly be seen. This assembly code is in the lines between the keywords CODE and ENDCODE in the architecture descriptions of each process. The description of how the channels carry data between processes is written in the Hardware Description Language, VHDL (IEEE Std 1076-1993). Figure 7 illustrates how the three processes of Producer, Modifier and memWrite are linked by channel1 and channel2.

Most of the details of the VHDL and assembler code are not material to the present invention, and anyone skilled in the art will be able to interpret them. The material points are:-

Each process, defined by a VHDL entity declaration that defines its interface and a VHDL architecture declaration that defines its contents, is by some

means, either manually or by use of an automatic computer program, placed onto processors in the system, such as the array in Figure 1.

- 5 For each channel, the software writer has defined a slot frequency requirement by using an extension to the VHDL language. ~~This is the "@" notation, which appears~~ in the port definitions of the entity declarations and the signal declarations in the architecture of
- 10 "toplevel", which defines how the three processes are joined together.

The number after the "@" signifies how often a slot must be allocated between the processors in the system that are running the processes, in units of system

15 clock periods. Thus, in this example, a slot will be allocated for the Producer processes to send data to the Modifier process along channel1 (which is an integer16pair, indicating that the 32-bit bus carries

20 two 16 bit values) every 16 system clock periods, and a slot will be allocated for the Modifier process to send data to the memWrite process every 8 system clock periods.

25 entity Producer is
 port (outPort:out integer16pair@16);
 end entity Producer;

architecture ASM of Producer is

30 begin STAN
 initialize regs:= (0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0);
 CODE
 loop
 for r6 in 0 to 9 loop

35 copy.0 r6,r4
 add.0 r4, 1, r5

```

        put r[5:4], outport
    end loop
end loop
ENDCODE;
5  end Producer;

```

```

entity Modifier is
10  port (outPort:out integer16pair@8;
        inPort:in  integer16pair@16);
end entity Modifier;

architecture ASM of Modifier is
15  begin MAC
    initialize regs:= (0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0);
    CODE
    loop
        for r6 in 10 to 19 loop
20          get inport, r[3:2]
            add.0 r2, 10, r4
            add.0 r3, 10, r5
            put r[5:4], outport --This output should be
input into third AE
25          end loop
        end loop
    ENDCODE;
end Modifier;

```

```

30  entity memWrite is
    port (inPort:in integer16pair@8);
end entity memWrite;

35  architecture ASM of memWrite is
begin MEM

```

```

initialize regs:= (0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0);
initialize code_partition := 2;

```

```

CODE
copy.0 0, AP      //initialize write pointer
5  loop
    get inPort, r[3:2]
    stl r[3:2], (AP) \ add:=0-AP, 4, AP
    end loop
ENDCODE;
10 end;

```

```

entity toplevel is
end toplevel;

```

```

15 architecture STRUCTURAL of toplevel is

```

```

    signal channel1: integer16pair@16;
    signal channel2: integer16pair@8;

```

```

20 begin
    finalObject: entity memWrite
        port map (inPort => channel2);
    modifierObject: entity Modifier
25     port map (inPort=>channel1, outPort=>channel2);
    producerObject: entity Producer
        port map (outPort=>channel1);
    end toplevel;

```

30 As described above, the code between the keywords CODE and ENDCODE in the architecture description of each process is assembled into machine instructions and loaded into the instruction memory of the processor (Figure 5), so that the processor core executes these

35 instructions. Each time a PUT instruction is executed, data is transferred from registers in the processor

core into an output port, as described above, and each time a GET instruction is executed, data is transferred from an input port into registers in the processor core.

5

The slot rate for each signal, being the number after the "@" symbol in the example, is used to allocate slots on the array buses at the appropriate frequency. For example, where the slot rate is "@4", a slot must be allocated on all the bus segments between the sending processor and the receiving processors for one clock cycle out of every four system clock cycles; where the slot rate is "@8", a slot must be allocated on all the bus segments between the sending processor and the receiving processors for one clock cycle out of every eight system clock cycles, and so on.

Using the methods outlined above, software processes can be allocated to individual processors, and slots can be allocated on the array buses to provide the channels to transfer data. Specifically, the system allows the user to specify how often a communications channel must be established between two processors which are together performing a process, and the software tasks making up the process can then be allocated to specific processors in such a way that the required establishment of the channel is possible.

This allocation can be carried out either manually or, preferably, using a computer program.

Figure 8 is a flow chart illustrating the general structure of a method in accordance with this aspect of the invention.

In step S1, the user defines the required functionality of the overall system, by defining the processes which are to be performed, and the frequency with which there need to be established communications channels between
5 processors performing parts of a process.

In step-S2, a compile process takes place, and software tasks are allocated to the processors of the array on a static basis. This allocation is performed in such a
10 way that the required communications channels can be established at the required frequencies.

Suitable software for performing the compilation can be written by a person skilled in the art on the basis of
15 this description and a knowledge of the specific system parameters.

After the software tasks have been allocated, the appropriate software can be loaded onto the respective
20 processors to perform the defined processes.

Using the method described above, a programmer specifies a slot frequency, but not the precise time at which data is to be transferred (the phase or offset).
25 This greatly simplifies the task of writing software. It is also a general objective that no processor in a system has to wait because buffers in either the input or output port of a channel are full. This can be achieved using two buffers in the input ports
30 associated with each channel and two buffers in the corresponding output port, provided that a sending processor does not attempt to execute a PUT instruction more often than the slot rate and a receiving processor does not attempt to execute a GET instruction more
35 often than the slot rate.

There are therefore described a processor array, and a method of allocating software tasks to the processors in the array, which allow efficient use of the available resources.

CLAIMS

1. A method of automatically allocating software tasks to processors in a processor array, wherein the processor array comprises a plurality of processors having connections which allow each processor to be connected to each other processor as required, the method comprising:
 - receiving definitions of a plurality of processes, at least some of said processes being shared processes including at least first and second tasks to be performed in first and second unspecified processors respectively, each shared process being further defined by a frequency at which data must be transferred between the first and second processors; and the method further comprising:
 - automatically statically allocating the software tasks of the plurality of processes to processors in the processor array, and allocating connections between the processors performing said tasks in each of said respective shared processes at the respective defined frequencies.
2. A method as claimed in claim 1, wherein the method is performed at compile time.
3. A method as claimed in claim 1 or 2, comprising performing said step of allocating the software tasks by means of a computer program.
4. A method as claimed in claim 1, 2 or 3, further comprising loading software to perform the allocated software tasks onto the respective processors.
5. A computer software product, which, in operation performs the steps of:

receiving definitions of a plurality of processes,
at least some of said processes being shared processes
including at least first and second tasks to be
performed in first and second unspecified processors of
5 a processor array respectively, each shared process
being further defined by a frequency at which data must
be transferred between the first and second processors;
and

statically allocating the software tasks of the
10 plurality of processes to processors in the processor
array, and allocating connections between the
processors performing said tasks in each of said
respective shared processes at the respective defined
frequencies.

15

6. A processor array, comprising a plurality of
processors having connections which allow each
processor to be connected to each other processor as
required, and having an associated software product for
20 automatically allocating software tasks to processors
in the processor array, the software product being
adapted to:

receive definitions of a plurality of processes,
each process being defined by at least first and second
25 tasks to be performed in first and second unspecified
processors respectively, each process being further
defined by a frequency at which data must be
transferred between the first and second processors;
and to:

30 automatically allocate the software tasks of the
plurality of processes to processors in the processor
array, and allocate connections between the processors
performing each of said tasks at the respective defined
frequencies.

35

7. A processor array, comprising:

a plurality of processors,

wherein the processors are interconnected by a plurality of buses and switches which allow each processor to be connected to each other processor as

5 required,

wherein each processor is programmed to perform a ~~respective statically allocated sequence of operations~~, said sequence being repeated in a plurality of sequence periods,

10 wherein at least some processes performed in the array involve respective first and second software tasks to be performed in respective first and second processors, and

wherein, for each of said processes, required
15 connections between the processors performing said tasks are allocated at fixed times during each sequence period.

ABSTRACTPROCESSOR NETWORK

Processes are automatically allocated to processors in
5 a processor array, and corresponding communications
resources are assigned at compile time, using
~~information provided by the programmer.~~ The processing
tasks in the array are therefore allocated in such a
way that the resources required to communicate data
10 between the different processors are guaranteed.

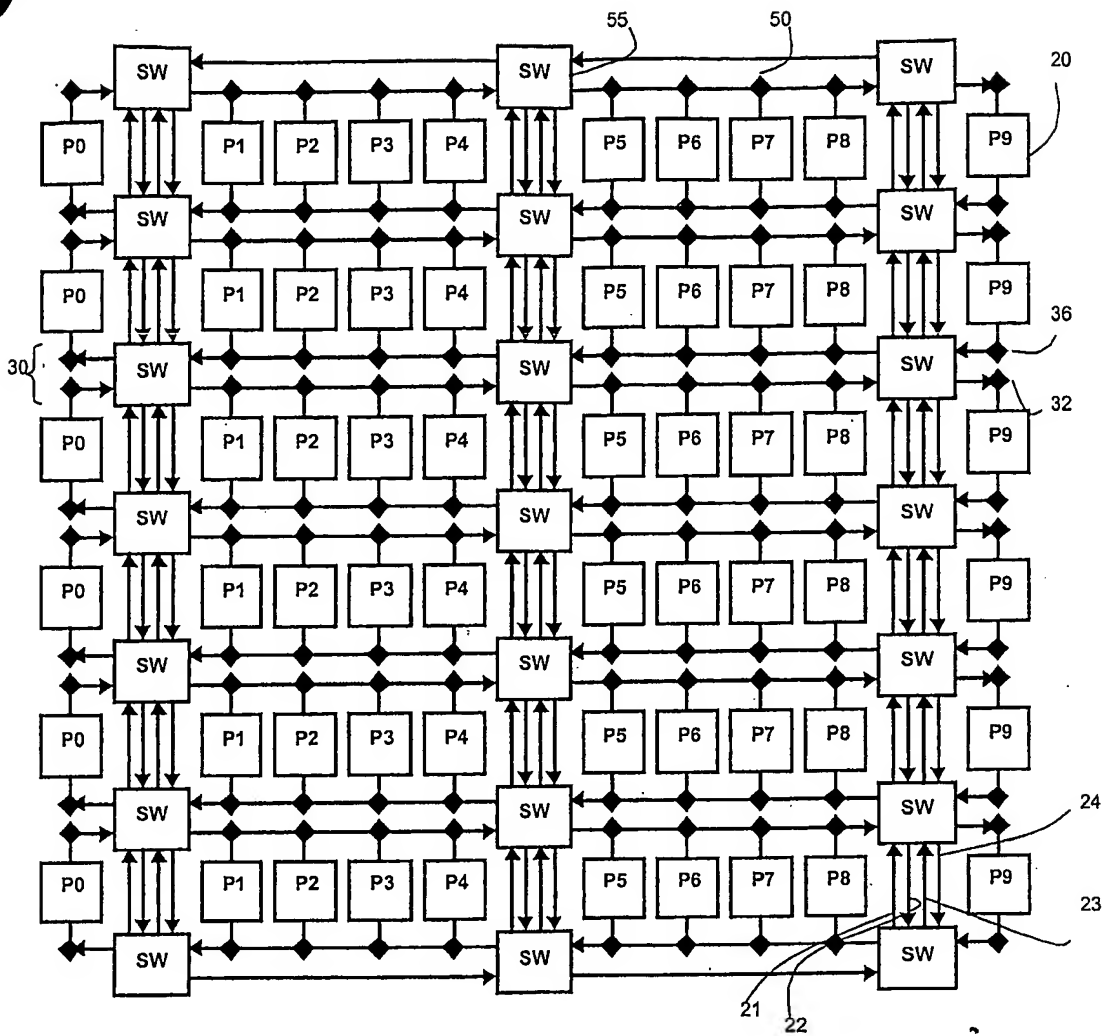


Figure 1

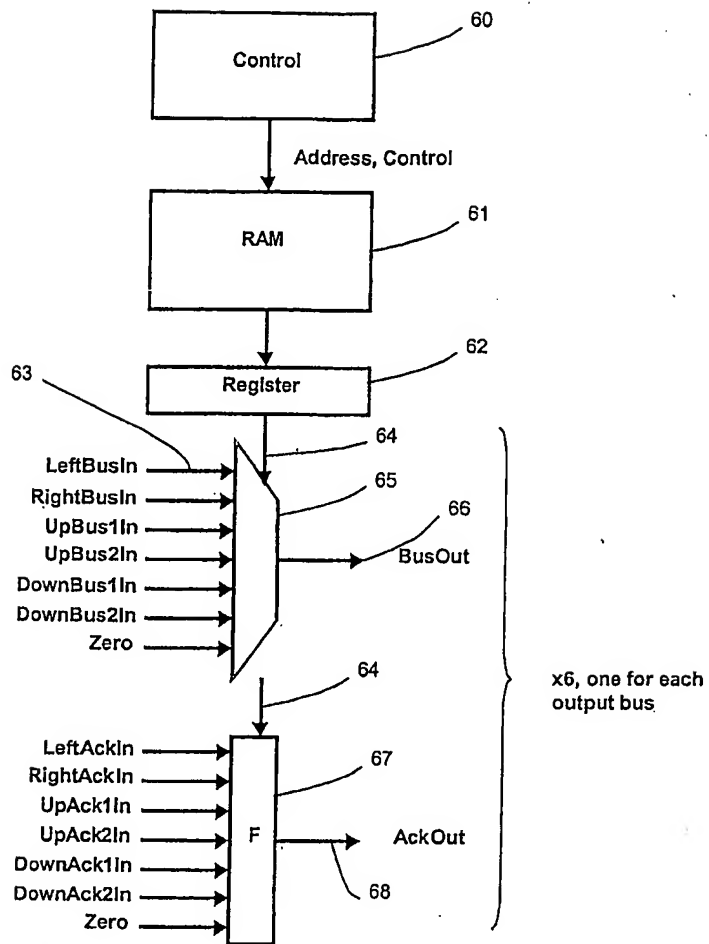


Figure 2

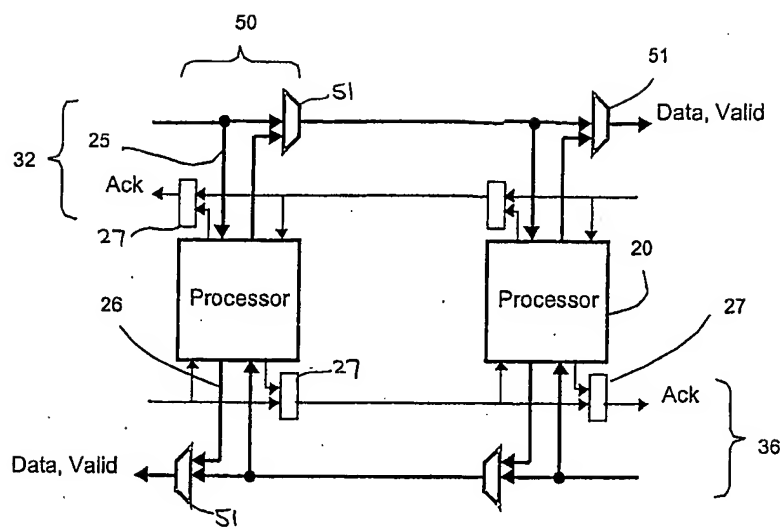


Figure 3

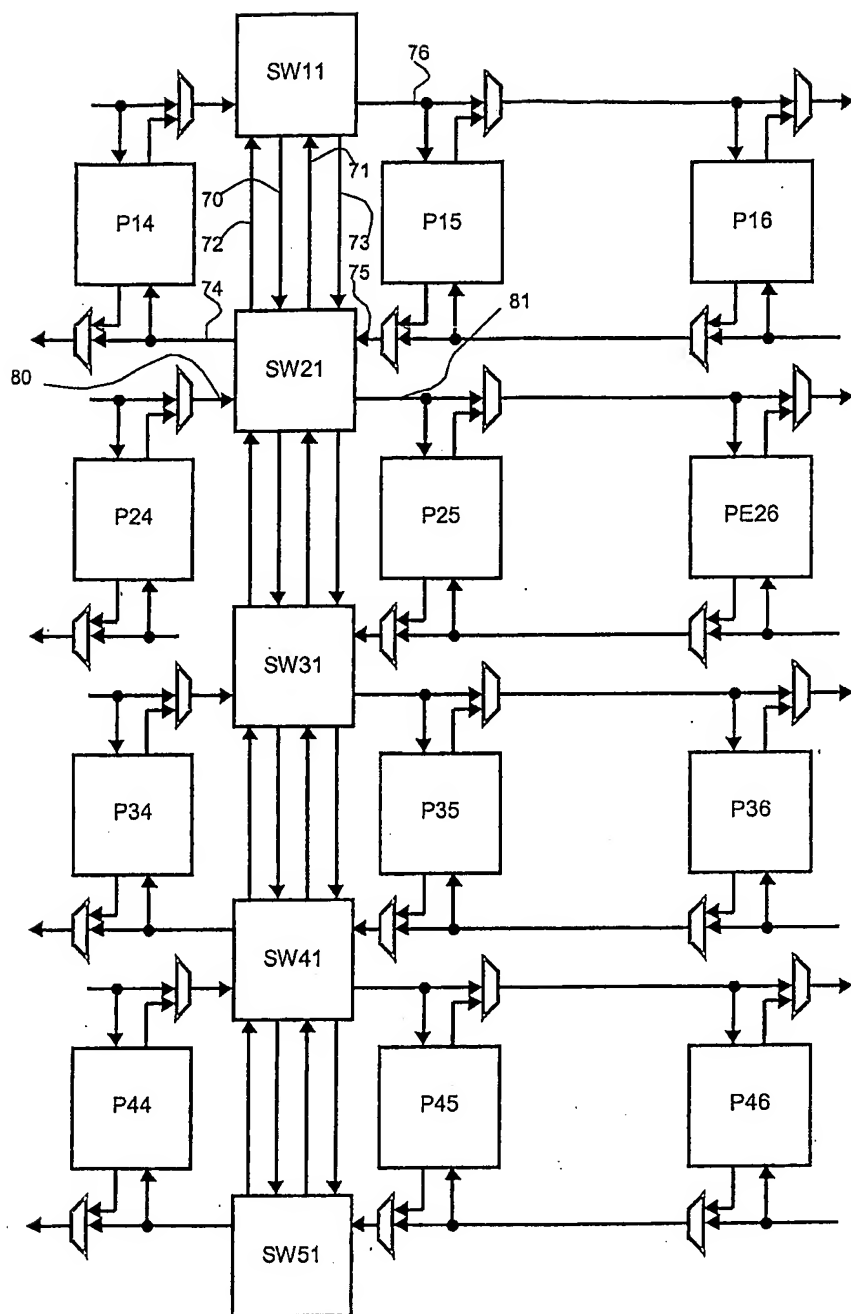


Figure 4

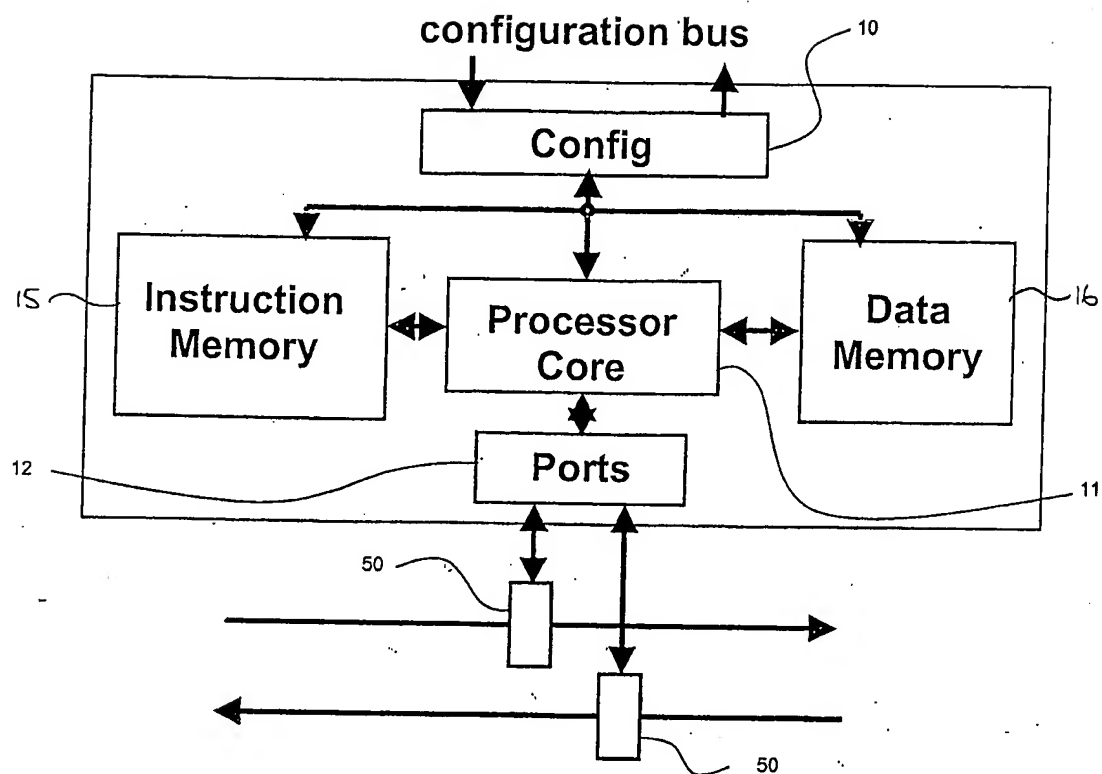


Figure 5

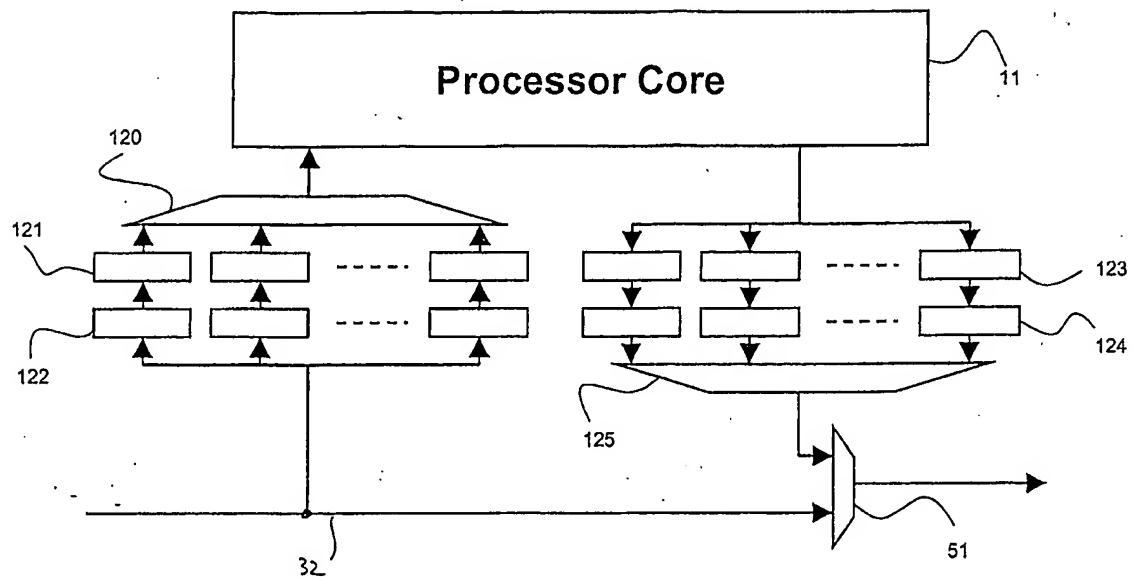


Figure 6

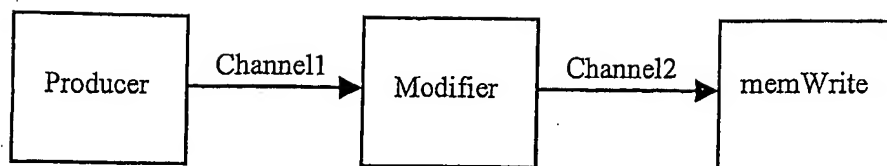


Figure 7

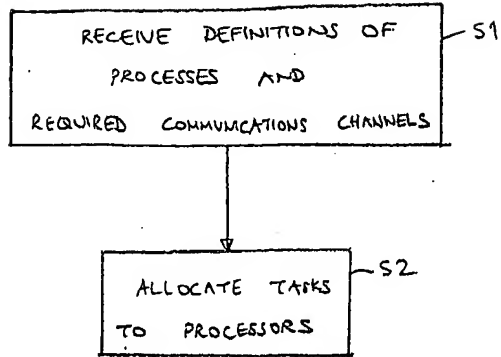


Figure 8



PCT Application
PCT/GB2004/000670

